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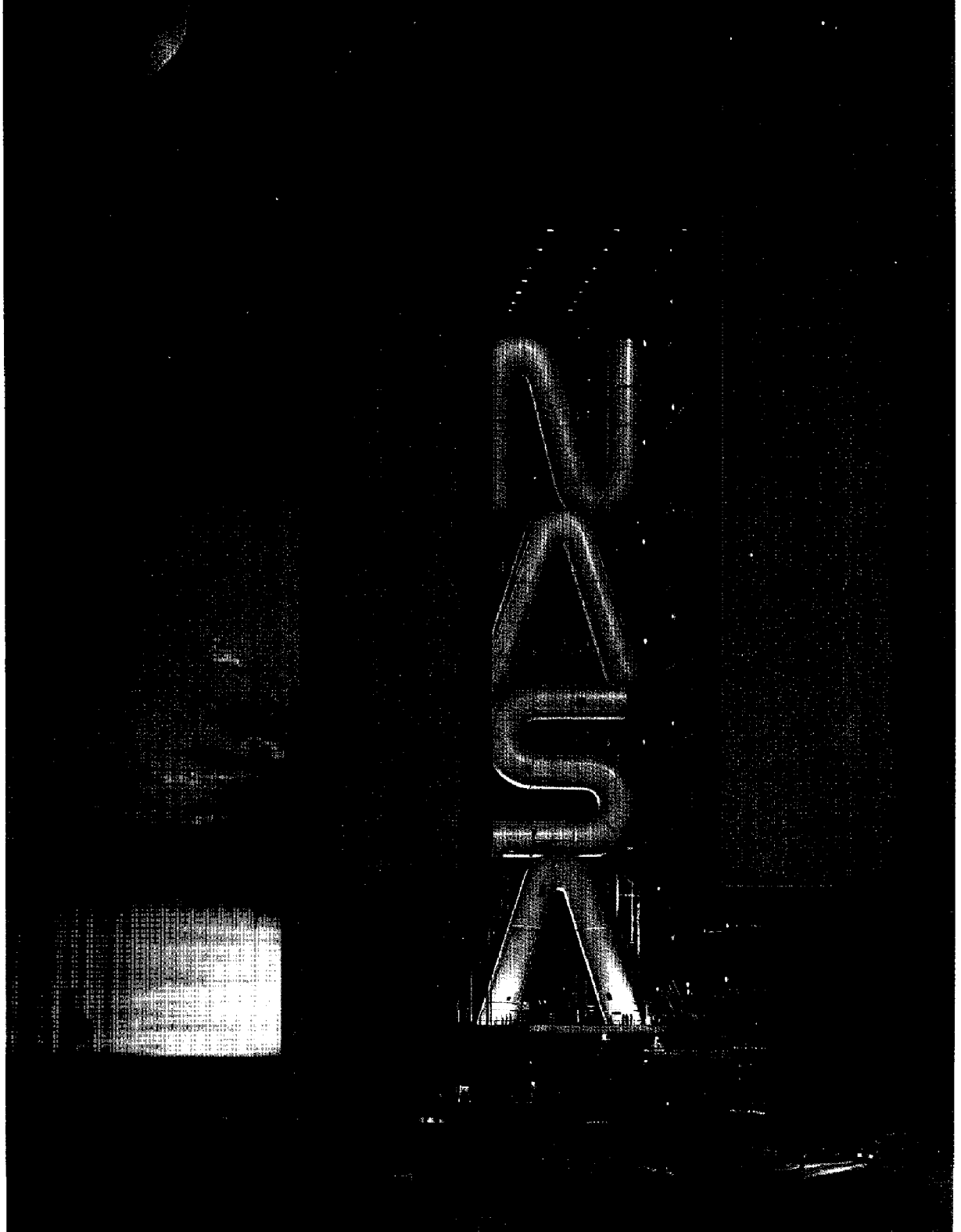

RETOOLING THE SPACE PROGRAM
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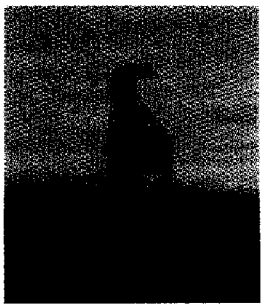

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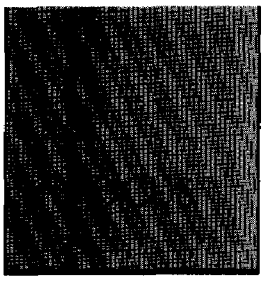


RETOOLING
THE SPACE PROGRAM

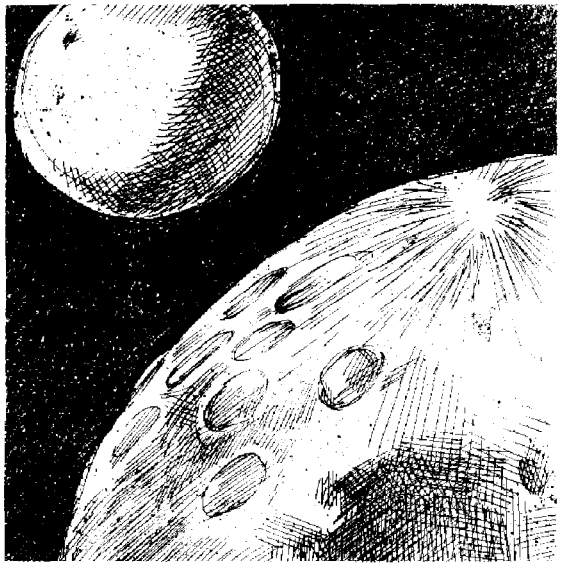
William K. Hartmann

TOWARD THE MOON, ASTEROIDS, AND MARS

Going to other worlds may answer questions about our own.

OVER THE LAST three decades, we have seen destructive arguments between the proponents of unmanned and manned exploration. The strictest-minded researchers, interested only in obtaining new measurements from instruments, argue that the next space program should consist only of unmanned black boxes sailing off to various planets, moons, asteroids, comets, and plasmas. To most of us—to most of the public, many scientists, and all space buffs—this is unsatisfying. Space exploration has been a human adventure as well as a mechanical means of data gathering. Data gathering is the rational side of space exploration, and human adventure is the less rational side. Is there any way to make a rational defense of human spaceflight? Twenty to forty billion dollars per planet is lot to pay just for the thrill of witnessing the first footsteps on virgin regolith (the unconsolidated residual surface material covering the solid rock of a planet or moon). And personally, I'd like space exploration to amount to more than the thrill that dune-buggy drivers get when they despoil the wilderness. It's a question of what kind of civilization we want to build. Space exploration ought to do *something* for our civilization. Does it?

I propose to evaluate our coming space opportunities in this context. In my view, the future exploration of the moon, asteroids, and Mars—robotic and human—ought to be an integrated program that reflects the kind of civilization we want to build. I think we should want, and actually do need, a program that involves a base on the moon; ongoing robotic reconnaissance of asteroids, Phobos, Deimos, and Mars; testing of asteroid resources; and probable eventual human exploration of Mars. Such a program would be driven not only by interesting intellectual challenges, like the origins of the solar system and of life itself, but also by practical concerns about what is happening on Earth: changes in our climate, impending exhaustion of mineral and fossil fuel reserves, and pollution by heavy industry. The program that we can choose to shape would be designed not only to give us science facts, but to see if we can



WILLIAM K. HARTMANN, an astronomer, writer, and painter, discovered several of the giant multiringed basins on the moon, co-authored a widely accepted theory of lunar origin, and served as a co-investigator on NASA's Mariner 9 Mars mapping mission. This article is adapted, with permission, from Blueprint for Space: Science Fiction to Science Fact, edited by Frederick I. Ordway III and Randy Liebermann (Washington, D.C.: Smithsonian Institution Press, 1992).

demonstrate human capabilities in space: to gain knowledge about how climate changes work; to discover metals and other resources in asteroids and to utilize them; and to demonstrate the potential for utilizing solar energy in space. The program would be a blend of data gathering and exploration, research and adventure, robotic and human activity.

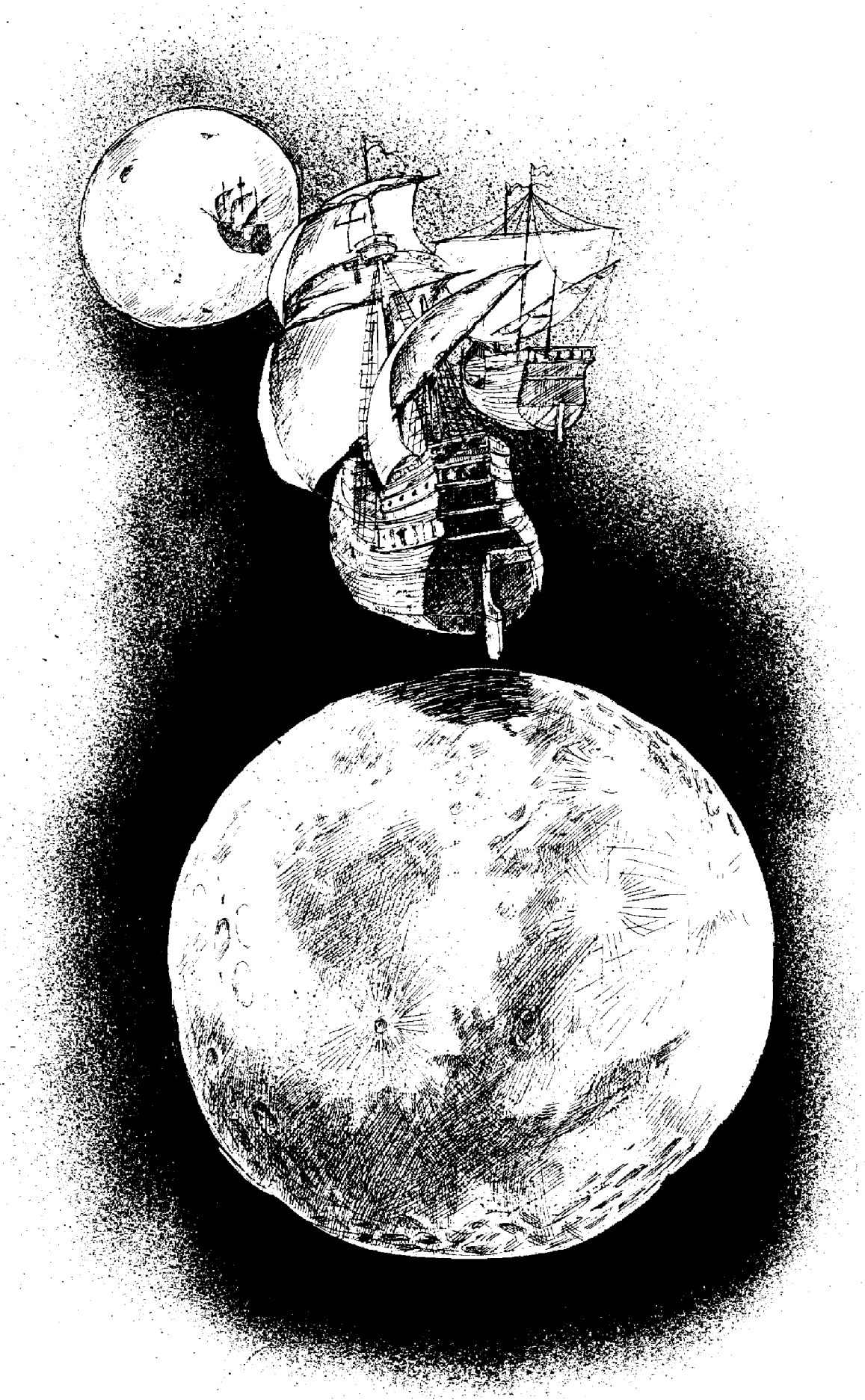
Where we stand: current plans

Every year in March, NASA's Johnson Space Center in Texas is the site of an annual Lunar and Planetary Science Conference. Each year, one night, "NASA Night," is devoted to presentations about the current state of the American program, and foreign visitors often present the latest plans of other space agencies as well. In recent years, the dismembered Saturn V booster from the Apollo program, lying on its side in the grass at the entry to the Johnson Space Center, often seemed to represent the air of gloom that hung over NASA Night. Always the NASA officials were upbeat: several missions were in the works; last year's cuts were awful, it was true, but this year there was a good chance that . . . etc. Often, however, researchers were cynical. Grant increases didn't materialize. Problems with the shuttle ate up dollars that might have gone into smaller, cheaper mission launches with expendable boosters. Arguments ensued between the black box researchers and the advocates of the shuttle and space stations.

One change in recent years was the tone of the Soviet presentations. In the 1970s and early 1980s, the Soviets were tight-lipped about their future plans. But from the mid-1980s on, with *glasnost*, the Soviets presented each year a more and more amazing program aimed at the moon and Mars. In March 1989, the upbeat Soviets outdid even their earlier performances. Their fresh new slides from the Phobos-2 probe showed the black Martian moon, Phobos, hanging in front of Mars. The Russian speaker who showed these was interrupted by a spontaneous ovation from the audience. Phobos-2 was even then closing in on Phobos to get even more impressive results.

The confident Soviet scientists went on to describe with slides and films the most ambitious program they had ever presented. A possible 1992 lunar orbiter would map lunar mineralogy. The Mars '94 twin probes would deploy Soviet-French balloons to drift over Mars for 10 to 12 days, covering several thousand kilometers, photographing surface features and touching down at night to gather ground data. In 1996, they planned two probes that would each fly by three or four asteroids and one comet, approaching one final asteroid close-up to deploy penetrators onto the asteroid's surface (this would be based on the design of the Phobos mission). A 1998 launch using the Energia booster would send a Viking-class lander and/or rover to the red planet to return with samples. At the end of the century might come a Mercury rover. Cosmonauts might reach the moon soon after 2000, with a lunar base established by 2010.

The Soviets emphasized the value of international cooperation on all these missions, especially the Mars sample return mission. Academician Valery Barsukov reported that during a November 1988 conference in Washington, the Soviets had invited Americans to participate in all their missions, so that there would be "no question of who is behind or who is ahead. We will both be ahead." Asked about the lunar base, he went on to remark, "I hope there are two flags flying on the lunar base." There was more applause.



an integrated scientific and practical program...

Within weeks, events dampened this optimism. Phobos-2 was lost, apparently due to mechanical malfunction, before it could accomplish its most challenging goals. (Contrary to impressions from Western press reports, however, Phobos-2 was not a total failure. It did get exciting new data, such as an improved measurement of Phobos's puzzlingly low density—similar to that of certain water-rich carbonaceous meteorites.) Severe criticism from Soviet journalists, scientists, and ordinary citizens was now leveled at the Soviet space program. The bold *perestroika* program at home was still meeting delays in improving the Soviet domestic economy. Letters to the editors of the newly opened editorial pages in the USSR became ever more critical: "We need groceries here; Mars can wait." In short, the future of the Soviet space program was uncertain even before the political upheaval of 1990 cast the future of the entire Soviet system into doubt.

In the United States, on July 20, 1989, President Bush used the 20th anniversary of the first footsteps on the moon to declare that Americans should return to the moon, establish a permanent presence there, and go on to Mars. At the March 1990 Lunar and Planetary Science Conference in Houston, there was therefore quite a new mood on the American side. NASA managers were clearly taking this as a mandate to begin planning with a scale and mood not seen since the Apollo days. Suddenly NASA Night featured slides of new, improved lunar landing modules and designs for piloted Mars landers.

The most encouraging thing from my perspective, however, was that all the NASA speakers stressed a vision of a coordinated program blending robotic and manned exploration, clearly intending to head off the kinds of arguments we had during the 1970s, when black box scientists blasted the shuttle and space station so vehemently and so publicly that it arguably hurt the whole program instead of improving it.

In 1989, President Bush declared that Americans should return to the moon and go on to Mars. NASA clearly took this as a mandate to begin planning on a scale not seen since Apollo.

As for missions on the American side, the Galileo probe was already on the way to Jupiter, the Magellan radar mapper already en route to Venus, and the robotic Mars Observer probe was awaiting launch for its 1992 mission to observe the atmosphere chemistry and some soil properties of Mars. So things seemed upbeat.

Recently, however, the American program has also suffered a setback. Incredibly, the Hubble Space Telescope, which had been expected to be the greatest advance in astronomy since Galileo, and which had awaited its launch in storage and test facility for several years due to the Challenger-induced delay in shuttle launches, turned out to have a serious design or manufacturing flaw in one or more of its main mirrors, and had never been adequately tested optically in final assembled form on the ground. Once it got into orbit, researchers discovered that it did not focus sharply. This was a stunning blow. Such a basic flaw in American design and engineering throws doubt on America's ability to design and fly challenging missions at the turn of the century. To add delay to injury, the complete shuttle fleet was grounded for many weeks at the same time due to an elusive leak in the fuel system.

So we are left with a real question about the future of space exploration. Europe and Japan are rapidly emerging as centers of space exploration. A consortium of European countries successfully built the Giotto probe that stared into the eye of Halley's comet without blinking; Japan has sent less sophisticated probes past Halley's comet and the moon. Yet the leading spacefaring nation, the United States, faces questions about the competence of its design, manufacturing, and/or quality control processes; and all major projected missions, from the European-American Cassini mission to Titan to the projected U.S. space station, are being questioned. In short, these are questions about the nature of our global technological civilization. Do we still have the will, funding, and ability to explore space? Will we decide that other activities are more important?

A practical program for the moon, asteroids, and Mars

Scientific as well as practical considerations favor a vigorous program in the coming decade that will focus on the moon, asteroids, and Mars. A number of forces are converging on this multi-pronged program, although these forces have not been widely recognized. They are as follows:

1. The general evolution of pure research questions in planetary science, particularly questions about the early history of planets and evolution of their surface environment.

2. The need to understand environmental influences that may cause climate change and ecological degradation of Earth.

3. The depletion of fossil fuel and mineral resources of Earth, including petroleum, coal, and metal.

4. The degradation of Earth's environment by dumping of industrial waste products into the ecosphere—a process that will increase as Third World countries try to emulate the consumer economies of developed countries.

5. The general political desire to apply findings from space research to terrestrial problems.

Space research may have answers to all five problems. In brief:

1. Exploration of the moon and asteroids provides access to rocks that reveal processes from 3.5 billion years ago, back to the beginning of the solar system 4.5 billion years ago; most Earth rocks are much younger than 3.5 billion years, because of Earth's active erosion processes.

2. Mars gives us a chance to study the most Earth-like planet, on which (to our surprise) a dramatic climate change happened that apparently ended a period of liquid water flow in rivers, causing a change to frozen, arid conditions.

3. Asteroids contain abundant metals and other resources.

4. If we can demonstrate the ability to process and refine the resources of asteroids *in space*, and utilize the 24-hour-per-day solar energy in space, we may be able to reverse the tide of industrial degradation of Earth.

5. All of these steps are dramatic examples of understanding the Earth better and applying our knowledge to exciting problems.

I will describe specific projects that I believe should be important elements in space exploration. Some of these diverge somewhat from the themes proposed by advisory committees of NASA and foreign space agencies, because they include more than purely scientific problems; they spill over into problems of practical application. There are four steps in the program.

A lunar base would offer the opportunity to study a problem of broad interest: the obliteration of many terrestrial species 65 million years ago, apparently as a result of the impact of one or more asteroids.

1. *Establish a lunar base.* A lunar base, in addition to being a site for repairable radio and optical observatories, low-gravity physiology experiments, etc., would offer a unique opportunity to study a problem of interest to a broad range of sciences: the obliteration of many terrestrial species 65 million years ago, apparently as a result of the impact of one or more asteroids. A concentration of asteroidal elements, together with soot and tsunami deposits, exactly in the soil stratum that marks the end of the Cretaceous period 65 million years ago has convinced many scientists that a 10-kilometer-diameter asteroid hit at that time, causing global forest fires and sending "tidal waves" rolling over parts of continents. Dust was thrown into the stratosphere, blocking sunlight for months, and climate changes wrought havoc in the food chain, eventually causing the extinction of dinosaurs and many species of animals and plants.

An important question for this theory is whether there was one random asteroid impact or a whole shower of asteroids (or comets). Some scientists have claimed that the few ancient impact craters on Earth are clustered in age, indicating periodic episodes of impact every 30 million years or so. Others go further and speculate that a distant, small, undiscovered star orbits around the Sun in this interval of time, disturbing the comet swarm that surrounds the solar system, causing waves of comets to crash into the planets every 32 million years or so. Still other scientists dispute this. A number of other unexplained episodes of extinction occur in Earth's fossil record, for example 32 and 240 million years ago. A high percentage of species died in each of these. But little firm evidence has been found to correlate these extinction catastrophes with an asteroid impact.

The cause of these extinction episodes is crucial to understanding the evolution of life on Earth. Biologist and historian of science Stephen Jay Gould has gone so far as to say that confirmed asteroid-impact extinctions would create a revolution in Darwinian evolution theory, because Darwin pictured evolution as fueled only by competition among species and individuals against a background of very slow geologic evolution; asteroid impacts would imply catastrophic changes caused by external forces from beyond Earth's ecosphere.

Interestingly enough, if we had a lunar base, we could test these ideas. We could send astronauts out to collect rock samples from say, 4,000 modest-sized impact craters nearby. Dating techniques would establish the age of each crater. We could then plot the frequency of impact during Earth's and the moon's history, with a resolution of about 1 million years. The results would indicate whether Earth has really been subjected to periodic waves of impacts or only random blasts. Such results, in turn, would be of high interest not only to lunar scientists but to planetologists, astronomers, paleontologists, biologists, and others.

2. *Conduct asteroid reconnaissance.* We already know from telescopic spectral observations and comparisons to meteorite samples that different spectral classes of asteroids exist, of different compositions. Some contain rich metal resources. Most of us recall seeing pure nickel-iron alloy meteorites in museums. These are broken pieces of asteroids that have melted and differentiated into metal portions and stony portions, like the iron and slag components in a smelter. Apparently the nickel-iron is exposed in many asteroids, and there may be several-kilometer chunks of pure metal on Earth-approaching orbits, as well as in the more populous asteroid belt. Other types of stony asteroids, as we know from meteorite samples, contain concentrations of other resources, such as the platinum-group metals. Still other asteroids contain water of hydration, or possibly ice, that may be a valuable resource for astronauts. Already at the University of Arizona and elsewhere, programs are under way to develop ways of utilizing these resources.

What we need to do is fly missions to a dozen asteroids and find out which spectral classes correspond to which compositions. In particular, which ones have high metal concentrations? And, are any of these among the group that approach close to Earth? These missions would be an extraordinarily important exploratory investment in our future. The reason is that nearly all projections of resource utilization call for exhausting the easily accessible reserves of metal ores and fossil fuels during the next century. We can be fairly sure that

Individual modest-sized asteroids could supply Earth's total consumption of certain minerals for decades.

significant economic and environmental change will result from this, possibly of grave discomfort to society. But if we can spend the next 10 years finding new resources in space, we have a way out. Evaluations of the total resource base in asteroid materials are remarkable. Individual modest-sized Earth-approaching asteroids, easier to visit than Mars, could supply Earth's total consumption of certain minerals for decades.

At this point, many readers object that such a program is a great mistake: a "disposable planet philosophy" that calls for exhausting Earth and then polluting space. I view it the other way. Pollution of interplanetary space is a relative non-problem, since the entire mass of Earth is hardly enough to cause noticeable debris in the space from Venus to Mars; and, if processed into dust or smoke, it would be soon swept out of the solar system by the solar wind. The real problem to us as a species is our continuing to dump our waste into our planet's ecosphere. Today, we are digging ever deeper, getting ever lower grade ores and fuels, and dumping the industrial by-products (from carbon dioxide to plutonium, from ozone-destroying gases to plastic debris) into our ecosystem. If we could find metal resources in space and demonstrate the technology to use solar energy to refine them, also in space, then we could begin to let our planet relax back toward its natural state, while we transfer our heavy industry into space.

This scheme to save the Earth is not yet economically viable. But every year, total costs of materials go up as ore gets poorer and harder to get and we pay for the environmental costs of processing them, while the costs of operating in space go down. Some day the curves will cross. We in this generation need to lay the groundwork, so that our grandchildren will know what opportunities are available in space.

3. *Reach Mars orbit and visit Phobos.* Tied into the asteroid program, and beginning our Mars program, will be the effort to reach Mars orbit and to study the satellites of Mars, Phobos and Deimos. This will be done first by robotic probes (as has already begun) and then by humans.

Phobos and Deimos are small, black objects that appear to be the same as a class of black asteroids found in the outer half of the asteroid belt. They may have originated as asteroids and been captured by Mars. As such, they give us a chance to study a remote, strange type of asteroid on the way to Mars.

Two benefits result. First, we learn more about origins of asteroids and satellites. Second, we could use Phobos as a ready-made space station and supply base for Martian exploration. The black type material on Phobos is believed by some researchers (including myself) to contain water beneath its dehydrated surface, either in molecular form chemically bound in hydrated minerals or as ice. Thus, it may have resources valuable to Mars astronauts.

Some visionaries have even suggested establishing "Phobos University." The first human expeditions to Mars, instead of being quick round-trip dashes, might instead plan to colonize Phobos as a study base for several years, with crews rotating through a permanent facility. It would basically be a case of shipping space station modules to Mars.

In the past, Mars's atmosphere was thicker. Where did the air go? Why? If we knew, we could perhaps better understand the climate change affecting Earth today.

4. *Explore the surface of Mars.* Here the goal would be to solve the greatest mystery of Mars: how it went from a planet with running rivers (2 or 3 billion years ago) to a frigid, extremely dry planet today. Do not misunderstand the word "dry." It means that there is no liquid water on Mars today. But the water is there, in three forms: ice in the polar cap, ice in underground permafrost layers, and water hydration in various minerals.

Strangely enough, Mars has many ancient-looking dry riverbeds. If liquid water were exposed on Mars today, it would rapidly boil away or freeze. The atmosphere is too thin to allow liquid water to be stable. Apparently, in the past, the atmosphere was thicker. Where did the air go? How did the atmospheric density and chemistry change? Why? How long ago did the river channels splash with swirling currents? If we could answer these questions, we could perhaps better understand the processes of climate change that are affecting Earth today.

This fourfold program of space research would make an integrated scientific and practical program, easily understood by the public. It would not only have benefits for academic scientists in many fields but could have direct payoffs to society. It would be a gamble, but an exciting gamble in which all residents of Earth could share vicariously. During any stage of our exploration, if we began to find that the asteroids or Mars did not live up to our expectations, we could pare back our efforts. On the other hand, the program might lead to an interplanetary economy matching the dreams of science fiction writers. •

Mark E. Gebicke

NASA: CHOICES AND CHALLENGES

Many of the problems facing the space program have down-to-earth solutions.

FEW FEDERAL AGENCIES work in an environment as demanding as that surrounding the National Aeronautics and Space Administration. NASA aims for 100 percent success on each space mission, and the nation expects no less. But such perfection is hard to achieve. By definition, NASA's missions are both highly complex and highly risky. And they are carried out under intense public scrutiny.

NASA has earned its reputation for monumental achievements. This is the agency that put the first human on the moon, shepherded Voyager through its 12-year journey to the outer planets, and continues daily to add to scientific knowledge and engineering know-how.

But the public often magnifies failures more than successes—and some failures are bound to occur. NASA's missions, manned and unmanned, depend on some of the world's most advanced technology. That complexity has always created plenty of opportunities for error. For example, the Saturn V rocket, which operated without a single failure during the Apollo program 20 years ago, required about 6 million components, manufactured by thousands of different contractors. Today, NASA must go though 1.2 million separate procedures to prepare a space shuttle for flight. The malfunction of just one crucial component can lead to a catastrophic loss such as the explosion of the Challenger space shuttle in January 1986. The government, the press, and the public, remembering the horror of that event, have since turned an ever more critical eye on NASA's projects.

The result is that, as NASA enters its 34th year, its recent problems have become all the more prominent: hydrogen leaks in the space shuttle's fuel tanks and malfunctions in the Hubble Space Telescope, costly delays in producing acutely needed weather satellites, and the recent antenna deployment failure that threatens the Galileo mission to Jupiter. If such problems persist, NASA's image, as well as its financial health, may be in peril.

So far, NASA's annual budget has fared amazingly well, increasing from less than $8 billion in 1986 to more than $14 billion in 1992. This increase is especially significant in view of the funding pressure of the federal deficit and NASA's direct competition for appropriations with numerous federal agencies, some of whose activities have a more immediate effect on people's lives. In fact, the subcommittees that determine NASA's budget also have responsibility for funding the Environmental Protection Agency, the Department of Housing and Urban Development, and the Veterans Administration from the same pool of money. To many Americans, NASA programs may seem an expensive luxury compared with programs charged with cleaning up the environment, housing poor families, and assisting veterans. Recently, budget reality has begun to set in. NASA's appropriation for fiscal year 1992 represents only a slight increase over 1991, and the future no longer promises large annual increases.

MARK E. GEBICKE is Director of the NASA Issue Area of GAO's National Security and International Affairs Division.

NASA now stands at a crossroads between a glorious past and an uncertain future, with ill-defined goals and tight budgets. If NASA is going to continue to deserve the respect and support it has earned over more than three decades, it must directly address the issues that have recently called into question its competence and efficiency. Fortunately, because many of NASA's problems relate to its own management practices, much of the agency's fate is in its own hands. NASA will therefore have opportunities to deal with these basic nuts-and-bolts issues as it prepares for the exciting challenges of the coming years.

We at GAO are prepared to help NASA seize these opportunities. In the past three years, we have more than tripled the number of staff devoted to reviewing NASA's activities and have issued more than 40 reports. Our findings have covered a wide range of topics, but many of them fall within a few broad management areas: overall strategic planning, agency management of decentralized activities, management of programs and projects, and information management. If NASA can successfully address the questions we have raised in these areas, it will have made significant progress toward focusing its programs and designing and operating successful aerospace projects. NASA's initial receptivity to our recommendations leads us to believe the agency is on the right track.

The space agency cannot move into the future until it knows where it wants to go. An effective plan could help articulate both the route and the destination.

Strategic planning

One of the most important issues facing NASA—as with all agencies—is to clarify where it is headed and at what cost. "If NASA is to provide the technological leadership necessary to put the United States at the forefront of advancements in aeronautics, space science, and exploration, it must develop a strategic plan that clearly states its vision for the future and the steps to realize that future in an affordable manner," we wrote late in 1988.[1] At that time, all signs indicated that NASA would soon issue strategic plans for each of its program offices and for the agency as a whole. We urged NASA to set a timetable for completing this planning process. Yet, three years later, the NASA-wide plan and some of the program office strategic plans are still not in place.

The first delay came soon after we issued our two 1988 reports on NASA's strategic planning process. NASA eliminated its Office of Planning and put the development of an overall strategic plan on hold. A year or so later, NASA Administrator Richard Truly renewed efforts to devise a NASA-wide strategic plan, but the project was put aside amid a series of events: technical problems with the Hubble Space Telescope and the space shuttle; debates over the space station's purpose, design, and cost; and the work of two high-level committees—the Augustine Commission on the Future of the U.S. Space Program and the Stafford Commission on America's Space Exploration Initiative. One reason for the new delay may have been that each of these events had the potential to affect long-term planning, and officials may therefore have decided to wait until these issues were settled. Or long-term planning may simply have fallen to a lower priority in the swirl of more pressing events.

Planning efforts resumed once more in March 1991, and as of this writing in December 1991, a plan is being drafted. Recent congressional interest is adding impetus to this effort. On September 27, 1991, House and Senate conferees on NASA's fiscal year 1992 budget appropriation directed the agency to complete a plan concurrently with its fiscal year 1993 budget submission.

Done well, strategic planning enables an organization to clarify its vision, set goals and objectives to achieve it, assess alternative approaches, and identify and resolve potential problems. While this would be essential for any agency, it is particularly important for NASA now. Although President Bush has stated that he would like the United States to return to the moon and go on to Mars, no consensus has been reached with Congress and the space agency. In short, NASA as yet has no clearly defined long-term mission—in stark contrast to previous decades, when the "space race" motivated the

agency's work. NASA cannot move past the present and into the future until it knows where it wants to go. An effective plan could help articulate both the route and the destination, giving the agency a more cogent voice in the public debate over its future size and direction.

Managing decentralized activities

Perhaps the most prominent feature of NASA's institutional culture—a characteristic we have noted in study after study—is the importance it places on the independence of its many decentralized research and space centers. Its nine field centers operate virtually independently, and each has a distinct identity.

Decentralization, in itself, is not a problem. But for such an approach to work effectively, headquarters must offer clear guidance (in the form of agencywide policies and standards) and careful oversight. Ineffective guidance and oversight from headquarters increases the risk of inconsistent and substandard performance throughout NASA. This risk increases even further when resources are scarce, forcing administrators to choose between "housekeeping" activities and program efforts.

NASA would benefit from strengthening headquarters' oversight in such areas as environmental

managing decentralized activities

control, facilities maintenance, procurement management, and testing. In each of these areas, decisions on allocating time, effort, and money have been left up to each center, and some great disparities have arisen across the agency. Setting and enforcing agencywide standards would not necessarily change NASA's decentralized culture, but it would help control inconsistencies and ensure an acceptable minimum level of performance across the agency. NASA seems to agree, and has taken, or is planning, corrective action in each area.

Environmental control

NASA's operations produce vast amounts of hazardous wastes and often involve dangerous chemicals. Given the nature of NASA's work, it is not surprising that environmental problems occur—for example, groundwater contamination, exposed asbestos, and mercury spills.

Although NASA's policy is to control and reduce environmental pollution, NASA headquarters does not have an agencywide strategy for pollution-control activities. The field centers are responsible for these tasks, but their efforts have not always complied with federal, state, and local regulations.

NASA should establish a uniform strategy, including measurable center-based goals, for pollution control and abatement.

Lacking central oversight, NASA cannot routinely learn of serious noncompliance problems, ensure that problems identified at one center are investigated at other centers with similar facilities, or guarantee that centers perform periodic audits of environmental compliance.[2]

Two of the five centers we visited in 1990 gave their environmental programs high priority and assigned them sufficient staff and resources. Overall, the environmental program at Johnson Space Center in Houston is considered one of the agency's best managed. Also, Lewis Research Center in Cleveland—which drew considerable media attention in 1989 for hazardous spills that were not immediately cleaned up—has reorganized and restaffed its environmental program and given it greater authority and visibility.

At the other three centers, however, we found the environmental programs understaffed or underfunded. For example, at Ames Research Center in Moffett Field, Calif., only one full-time civilian employee had environmental responsibilities. Her duties as regulatory specialist, hazardous waste program manager, and chemical spill response coordinator left her no time to conduct required inspections of commercial off-site treatment, storage, and disposal facilities used by the center. At that time, Ames was in violation of several county requirements on such matters as hazardous waste labeling, container management, and equipment to control fires and spills. Similar problems stemming from insufficient staff training or resources were also evident at Goddard Space Flight Center in Greenbelt, Md., and at Marshall Space Flight Center in Huntsville, Ala.

NASA needs to take several specific actions to strengthen its environmental management. It should establish an agencywide strategy, including measurable center-based goals, for pollution control and abatement. It also should establish standards for the size and skills of environmental staff at the centers and identify funding needed to carry out necessary tasks. Finally, it should provide guidelines for center reporting of environmental problems, make sure that information on problems reaches other centers with similar facilities, and periodically audit the centers' compliance with environmental regulations.

Facilities maintenance

A similar problem exists with facilities maintenance: The field centers lack guidance from headquarters on scheduling and funding repairs to NASA's nearly 6,000 buildings and other facilities. Because maintenance funding is largely left to each center's discretion, allocations vary widely even among centers of comparable age or mission. While some centers are strongly committed to performing scheduled maintenance, others do not assign it such a high priority; when faced with a funding crunch, they tend to defer maintenance and devote money to programs instead.[3]

This, in turn, raises the risk of equipment failures and costly repairs—or physical harm to people or property. For instance, a cooling tower at Lewis

partially collapsed from the weight of ice that accumulated because of faulty water valves. Loose wiring caused a fire in a mission control building at Marshall. And at Florida's Kennedy Space Center, NASA had to install netting to catch concrete falling from the roof of the 52-story building in which the space shuttle is assembled.

To prevent the costly problems that tend to follow deferred maintenance, NASA should make facilities maintenance a vital management commitment.

A widely accepted standard from the National Research Council prescribes annual maintenance outlays of at least 2 to 4 percent of the facilities' replacement value. Between 1985 and 1989, NASA's centers fell far short of this standard, annually spending between 0.9 and 1.5 percent of their facilities' replacement value on maintenance (except for the Jet Propulsion Laboratory in Pasadena, Calif.—operated for NASA by the California Institute of Technology—which spent 2.3 percent).

NASA recognizes that in the long run, carrying out preventive maintenance is far less expensive than correcting deficiencies once they occur, and has begun to work with the centers to assess their facilities' conditions. But to prevent the costly problems that tend to follow deferred maintenance, NASA should set guidelines for identifying and addressing maintenance needs, impose some minimum standards for budget allocations, and make facilities maintenance a vital management commitment of center directors and heads of headquarters' program offices.

Procurement management

NASA headquarters can also do more to target its oversight of field centers' management of contracts and contractors. Four NASA centers (Goddard, Marshall, Kennedy, and Johnson) together spend over 70 percent of NASA's annual procurement budget of more than $12 billion. Our survey of a sample of contracts awarded by these centers between 1984 and 1989 showed that about one-third of these contracts experienced cost increases and more than two-fifths underwent time extensions.[4]

The degree of these cost and time changes varied considerably from center to center. For instance, annual growth in contract costs ranged from 0.4 percent at Goddard to 6.6 percent at Kennedy. Similar broad variations existed between different types of contracts (fixed-price or cost-reimbursable) and among different types of products (research and development, support services, or supplies and equipment).

We based our review on a statistical sample because NASA's centralized database of procurement information is unable to track contract time extensions and cost increases. That means NASA cannot monitor these types of contract changes at individual centers over time or compare them among centers. But the database does contain the necessary basic data elements, and programming improvements could enable NASA to routinely and comprehensively generate information on contract cost and time changes. Such information would help the agency better target its efforts to oversee procurement management.

Testing

Because space equipment cannot be easily repaired in orbit, it is especially important that it be thoroughly tested before launch. But deciding on an appropriate test program is hardly a simple matter. Systems are not mass-produced—most, in fact, are one-of-a-kind. As a result, testing programs must be tailored specifically for each project. But while each test program is unique, there should be a general framework within which to plan, conduct, and interpret tests.

NASA, however, has no uniform policies governing testing.[5] Different field centers have developed their own policies and procedures for testing; some methods vary even within centers. While testing for most of NASA's projects appears to be adequate, discrepancies in testing approaches become a problem when different centers design parts for a single project. In such cases, hardware designed for the same mission may be tested to different standards.

For example, until recently, each of the four centers developing space station hardware planned to use its own testing criteria for the program. Under this procedure, different parts of the station would have been tested to different tolerances for

environmental extremes of heat and cold, under different durations of exposure. After a space station review team expressed concern over this variation, program officials drafted environmental testing criteria to apply to all space station hardware.

While this is good news for the space station and a good first step, NASA should now develop the means to ensure that such standards exist for all projects. This would involve issuing agencywide policies and minimum requirements and defining responsibilities for planning and conducting tests and reporting results. NASA agrees that it needs an overall testing policy, and it has begun to address the issue.

Program and project management

NASA's most significant operational challenge involves the management of its programs and projects: The agency must work to identify and mitigate problems that can significantly raise costs, disrupt schedules, and impair performance. Clearly, this is no easy task. Space projects are not only technologically challenging and risky, they are also vulnerable to external influences, such as weather and astronomical conditions (which affect launch schedules) and year-to-year variations in funding.

As long as NASA plans more than it can pay for, it cannot avoid wide variances between what it promises and what it finally delivers.

While such factors are beyond NASA's control, others are not. In some instances, the problem is simply inadequate project management. Recent projects offer some examples:

Project "stretch-out": The Orbital Maneuvering Vehicle. When NASA fails to recognize the reality of today's budget environment and is then unable to fund each of its many projects at the pace it had planned, it typically maintains all or most of them at reduced levels. Their schedules are then stretched out to subsequent years. That costs even more in the long run. These projects are, in turn, often cut back to more modest goals to make up some of the loss in time and money. In short, after repeated "stretch-outs," projects generally cost far more than planned, yet accomplish less than originally intended.

The example of the Orbital Maneuvering Vehicle (OMV)—a reusable satellite transporter to extend the reach of the space shuttle—demonstrates the extremes to which this cycle can run.[6] The Challenger accident and subsequent three-year hiatus in shuttle missions delayed the launch of many of the payloads the OMV was being designed to transport. As a result, the OMV fell below other projects in priority, and it suffered accordingly when NASA was forced to make funding choices. In three years, its estimated cost increased by 82 percent—from $405 million to more than $736 million—mostly because of schedule stretch-outs. At the same time, NASA reduced or eliminated so many of the vehicle's planned capabilities that eventually the prospective OMV had no useful, cost-effective purpose. In the summer of 1990, shortly after we sent NASA a draft report recommending that the project be cancelled entirely, NASA terminated the OMV, citing budgetary pressures and the lack of a firm, near-term need. By the time NASA decided to bite the bullet and cancel the program, it had already spent about $220 million—more than one-half of its original cost estimate, but far less than its final estimate.

We can see similar problems with the space station. The station design has been changed several times since fiscal year 1987 to accommodate concerns about its affordability. As a result, projected completion of the station has slipped from 1994 to 1999. At the same time, the estimated cost of assembling and outfitting the station has grown from about $12.2 billion to possibly as much as $40 billion, while its potential uses have decreased from eight to one—a research laboratory for life science and microgravity.

Program stretch-out and reduced capabilities are a consequence of overly optimistic program planning and NASA's inability or unwillingness to make some hard choices. Simply put, NASA must set priorities; identify and pursue the most cost-effective alternatives within its major projects; and shelve low-priority projects rather then maintain them indefinitely at great expense. As long as NASA plans more than it can pay for, it cannot avoid wide variances between what it promises and what it finally delivers.

Underestimating difficulty: The GOES-Next weather satellite. NASA usually conducts extensive analyses early in the planning of new projects. Skipping these steps can lead to expensive problems later on. This is what happened with NASA's work on the next generation of weather satellites, called GOES-Next.

In its haste to produce a new satellite, NASA proceeded quickly into design and construction—only to discover that the new design raised a host of technical problems.

NASA expects the only functional geostationary U.S. weather satellite to reach the end of its service life in 1993. Unless NASA can put another satellite into orbit before this last one fails, the National Weather Service will be left without its best means to predict and track tornadoes, hurricanes, and other severe weather. But the highly touted replacement is now three years behind schedule, and program costs have more than doubled.

A major reason for this is that NASA officials significantly underestimated the difficulty of executing the new design.[7] Partly because of haste to produce a new satellite, and partly because officials believed the design would rely largely on existing technology, NASA dispensed with much of the detailed design analysis that normally precedes the award of contracts for new systems. Instead, NASA proceeded quickly into design and construction—only to discover later that the new design raised a host of technical problems. Additional analyses, redesigns, and remanufacture of parts led to increased costs and delays.

To compound its error, NASA did not initially assign enough qualified staff members to oversee the contractor developing instruments for the new satellite. Although NASA has increased its technical involvement, much of the damage—such as use of improper materials and other contractor errors—has already been done. Those errors are not easy to fix, and others may yet be discovered.

The Department of Commerce—the agency that pays for the GOES-Next satellites—has called for a 10-month delay in the program to address its technical problems. At the same time, the United States has entered into an agreement with the European Organization for the Exploitation of Meteorological Satellites to use an existing European satellite to minimize the risk of a loss of coverage. However, this agreement will support U.S. weather forecasting activities for only a limited period.

Incomplete cost estimates: Space Station Freedom. Until recently, all NASA's project cost estimates included only those project activities that would be funded under the project's "research and development" account in NASA's budget. Estimates did not include project-related activities funded under other accounts. This practice has hurt NASA's credibility; it is difficult to understand the logic of excluding, for instance, the cost of a space launch from the overall cost estimate for a space-based project.

That is precisely what happened with cost estimates for Space Station Freedom. The fiscal year 1987 estimate of $12.2 billion did not include the costs of the space shuttle flights needed to launch, assemble, and outfit the station, because those flights would be funded under the "space flight" budget account. Similarly, the estimate did not cover such related costs as ground facilities, personnel, operations, and equipping the station with scientific hardware.[8]

In its most recent space station cost estimate of $30 billion, NASA included some of the cost of shuttle flights. However, we told Congress in May 1991 that, when other costs are included, expenses could amount to about $40 billion.[9]

The difference between NASA's earlier and current cost estimates places it in an uncomfortable position. Observers may well wonder why the agency did not fully inform the public about the station's cost. Also, congressional decision-makers formed their initial opinions about the space station based on the earlier, lower estimates; had more complete figures been presented, the project might not have earned the same support. Ultimately, a full disclosure of the estimated cost of the station may prove to be the project's greatest liability.

Information management

Space missions generate massive amounts of data. Scientific data collected since 1958 include more than 1.2 million reels of magnetic tape as well as hundreds of thousands of charts, reports, microfilms, and photographs. But evidence in several

areas suggests that NASA is failing to identify and preserve valuable information.

Saving data

Since 1978, NASA's policy on space science data has specified that only the results of analyses by a mission's principal investigators be archived. This material represents only a small portion of the material gathered on the mission and is usually in a form unsuitable for additional analysis. Tapes containing original data are erased and reused. This represents a significant loss to science: Later investigators wishing to reexamine the information gathered by the mission, to analyze it in different ways, or to compare it with data from future missions cannot do so without the original, unprocessed data.[10] Moreover, data that do not interest the principal investigators—and are therefore discarded—may be valuable to other scientists.

Data from space missions do not always make it into the archives. NASA's archives lack complete data for some important missions and contain no data for others.

Even the information that meets NASA's criteria does not always make it into the archives. NASA's archives lack complete data for some important missions and contain no data at all for others. There are many reasons for these gaps. Some information has been lost simply because NASA has not required the archiving of data from certain types of missions or from NASA instruments flown on foreign spacecraft or the shuttle. Also, some data may be stored at other agencies or at universities, or staff or resources may have been insufficient to prepare data for archiving. Finally, many missions never had data management plans, which spell out instructions for archiving or destroying mission data. Only one of the 25 missions launched between May 1978 and October 1985 had such a plan.

Ideally, NASA should find and archive missing data from past missions, ensure that all valuable data are stored, and strengthen the participation of scientists—both inside and outside NASA—in identifying data worth keeping.

Protecting data

Even when it is saved, space science data may be in jeopardy simply because it is stored improperly. Federal regulations require government agencies to follow specific rules in maintaining and storing magnetic tapes. Early in 1990, however, we reported on widely varying storage practices at NASA—some of which posed physical danger to tapes.[11] In all, 8 of the 10 storage and processing facilities we visited did not comply with at least two of the applicable rules; many did far worse.

For example, we found tapes stored in hallways, basements, and warehouses not designed for tape storage. In one facility, we found nearly 300,000 tapes packed in boxes covered by dust and stacked on shipping pallets; in a basement, we saw tapes with obvious water damage from flooding. Some facilities did not have adequate temperature and humidity controls, fire or water protection, or tape maintenance. Some lacked basic security precautions to guard against unauthorized access to tapes. Only one facility maintained backup tapes so that data might be restored if the originals were lost, stolen, or destroyed.

NASA is working vigorously to improve these conditions. Besides improving physical storage facilities, the agency needs to conduct a thorough inventory of data stored at various facilities, assess those data for both their scientific value and their physical safety, and determine which material should be copied from deteriorating tapes to media suitable for long-term storage. Federal regulations already call for such steps. NASA will incorporate these procedures into agencywide records management policies it plans to issue this fiscal year.

Planning for data

In addition to dealing with information management issues involved in saving and protecting current data, NASA must also think about how it will handle future information management demands. The agency predicts that by the year 2000, it will amass more than 50 times more information annually than it collected in 1990.[12] The agency needs to plan now for handling data from major projects that are in relatively early stages of development.

One such project is the Earth Observing System (EOS), NASA's main contribution to the U.S. Global Change Research Program, the centerpiece of an international effort to study the earth and its ecosystems on a global scale. NASA plans to begin launching EOS equipment in 1998. Planners expect that EOS data, if stored by conventional means, would fill about 10,000 reels of standard magnetic tape each day. Over the life of the mission, that would amount to 1,000 times the volume of information stored in the Library of Congress.

NASA must overcome significant hurdles in determining which of this information to store and how to manage it. First, NASA will be one of the first users of new methods for mass data storage. Various manufacturers are developing promising new storage technologies, each requiring as-yet-unproven hardware and software.

Second, NASA must develop standards for the physical media on which data will be stored and the format of the stored data. Without such standards, users will have difficulty exchanging and comparing information from separate missions. The process of defining and adopting such standards can take several years.

NASA's newfound management emphasis will not lessen the need to make difficult choices among projects. If it tries to operate more programs than it can afford, Congress and the public will continue to question its competence.

A third task will be to pull together diverse information into a reliable system that enables scientists to find and use the data they want. The data management system that will support EOS will eventually manage more information than any other system in existence today. Building such a large and complex system will be a formidable—and expensive—undertaking.

Managing for the future

NASA obviously faces significant management challenges for the 1990s and beyond. To help meet these challenges, NASA's top management has been identifying and acting upon opportunities for improvement. For example, NASA has already implemented, or planned to implement, almost every recommendation we have made to the agency over the last few years. In addition, NASA has responded positively to recommendations from the Augustine and Stafford commissions.

This positive attitude will become even more important in the future as the space agency works to continue its scientific and engineering advances amid tightening budgets. However, this newfound management emphasis will not lessen the need to make difficult choices among projects. NASA must squarely face up to, and decisively make, such choices. If it does not do so, and tries to operate more programs than it can afford, Congress and the public will continue to question the agency's competence and efficiency, regardless of any other management improvements it might make. •

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1. See *Transition Series: NASA Issues* (GAO/OCG-89-15TR, November 1988). More detail on GAO's analysis of NASA strategic planning appears in *Civil Space: NASA's Strategic Planning Process* (GAO/NSIAD-89-30BR, Nov. 30, 1988).

2. See *Environmental Protection: Solving NASA's Current Problems Requires Agencywide Emphasis* (GAO/NSIAD-91-146, April 5, 1991).

3. See *NASA Maintenance: Stronger Commitment Needed to Curb Facility Deterioration* (GAO/NSIAD-91-34, Dec. 14, 1990).

4. See *NASA Procurement: Management Oversight of Contract Cost and Time Changes Could Be Enhanced* (GAO/NSIAD-91-259, Sept. 30, 1991).

5. See *Space Project Testing: Uniform Policies and Added Controls Would Strengthen Testing Activities* (GAO/NSIAD-91-248, Sept. 16, 1991).

6. See *Space Transportation: NASA Has No Firm Need for Increasingly Costly Orbital Maneuvering Vehicle* (GAO/NSIAD-90-192, July 31, 1990).

7. See *Weather Satellites: Action Needed to Resolve Status of the U.S. Geostationary Satellite Program* (GAO/NSIAD-91-252, July 24, 1991).

8. See *Space Station: NASA's Search for Design, Cost, and Schedule Stability Continues* (GAO/NSIAD-91-125, March 1, 1991).

9. See *Questions Remain on the Costs, Uses, and Risks of the Redesigned Space Station* (GAO/T-NSIAD-91-26, May 1, 1991).

10. See *Space Operations: NASA Is Not Archiving All Potentially Valuable Data* (GAO/IMTEC-91-3, Nov. 2, 1990).

11. See *Space Operations: NASA Is Not Properly Safeguarding Valuable Data From Past Missions* (GAO/IMTEC-90-1, March 2, 1990).

12. See *Space Data: NASA's Future Data Volumes Create Formidable Challenges* (GAO/IMTEC-91-24, April 8, 1991).

John M. Logsdon

LOST IN SPACE?

In a post-Apollo world, NASA has yet to find its bearings.

THE CIVILIAN SPACE program of the United States—carried out for over 30 years primarily through the activities of the National Aeronautics and Space Administration (NASA)—has deeply rooted problems. Those problems stem in large part from the way in which the program has evolved over the past three decades. That evolution has led to plans for a future in space that appear inconsistent with the priority that space now has on the national agenda.

To develop an approach to space that more nearly reflects that priority, the nation needs to rethink and reform its space program. Over the past two years, such a reconstruction has begun. But more changes are necessary before the United States once again has a space program of which it can rightfully be proud and, more important, that produces benefits for society that are commensurate with its costs.

It is instructive to think of the last three decades in space as a long and often exciting ride on a roller coaster. In 1961, President John F. Kennedy committed the United States to landing men on the moon, with the explicit goal of beating the Soviet Union to the feat and thereby demonstrating the nation's organizational and technological vitality. The Kennedy commitment and the re-

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sulting national mobilization of human and financial resources quickly lifted the space program to the top of the first high hill on the ride, and the rapid rush down that hill not only put 12 Americans on the lunar surface but also generated enough momentum to sustain the space program for most of the years since.

That momentum, rather than any carefully wrought decision about the next purpose for the space program, was sufficient during the 1970s to create political support for a vigorous space science program and a continuing program of human space flight centered on developing a reusable space transportation system. The same momentum was barely adequate to initiate a space

It has been difficult to identify the rationale for a new commitment to space. There is no longer a single issue of national importance to which "space" is the best response.

station program in 1984; by the mid-1980s it was clear that the civilian space program needed an injection of new energy—a lift up another high hill—if it was not to roll to a halt and perhaps begin to slide backwards. The post-Challenger desire to get the shuttle flying again masked broader recognition of this reality, but it has been obvious in the past few years to all who cared to look.

It has been difficult to identify the rationale for a new commitment to space. There is no longer a single issue of short-term national importance to which "space" is the best response, as it was in 1961 when President Kennedy asked his advisers to find him "a dramatic program in which we could win."[1] The source of new energy is not to be found in another external challenge.

Those seeking to reinvigorate the space program have turned instead to the long-held vision of creating a spacefaring civilization, one in which humans would establish permanent outposts on the lunar surface and undertake initial exploratory forays to Mars. This theme ran through the major analyses of the future in space carried out during the 1980s, such as the 1986 report of the National Commission on Space, the 1987 NASA report "Leadership and the Future in Space" prepared by Sally Ride, and the 1988 report of the National Academies of Science and Engineering, "Toward a New Era in Space." It culminated in President George Bush's call on July 20, 1989—the 20th anniversary of the first lunar landing—for a "sustained commitment" to human exploration of the solar system.

Whatever its considerable merits as the long-range rationale for putting humans in space, this call for going again beyond Earth orbit has not succeeded in giving the civilian space program the kick-start it needs. While most in the Congress and the U.S. public seem willing to accept the idea that humans will explore the solar system sometime in the 21st century, they also have indicated that now is not the time to make any but the most tentative new steps in that direction. If the space program is to have a strongly supported reason for its existence in this decade, that purpose will have to be something other than preparing for voyages of human exploration.

NASA as an institution

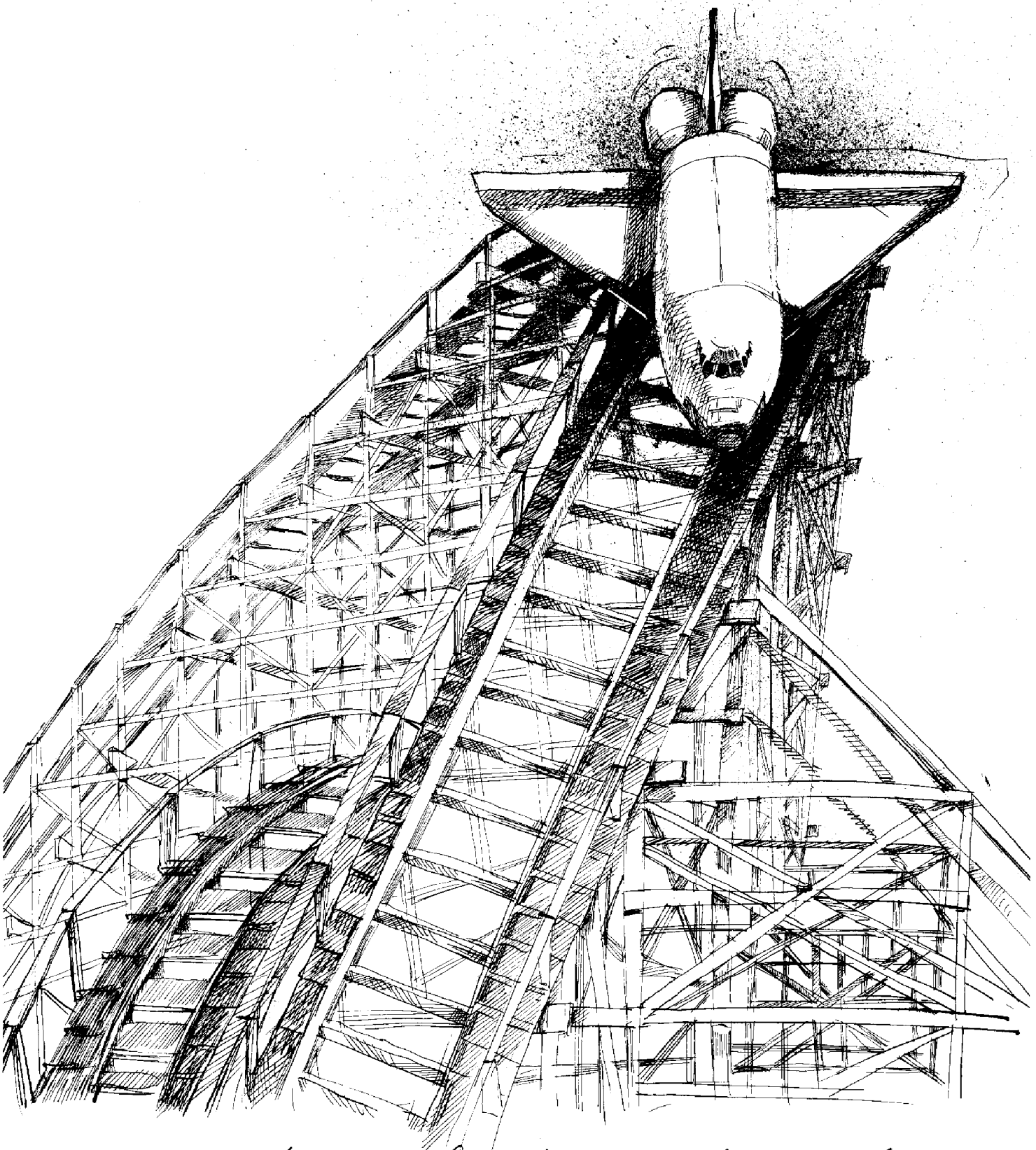
Caught up in continued uncertainty over its place in the national scheme of things, and lacking until very recently either presidential or congressional guidance, NASA has understandably tried over the past two decades to build on the pattern of success established during Apollo. This pattern involved the development of large hardware systems for both human and robotic missions and their launch and operation as highly visible, well-publicized national endeavors. At a basic level, NASA has been running a program of propaganda—a program to communicate a positive national image of vitality and competence. But the conditions that made this pattern so successful during the 1960s and early 1970s have largely been missing. While NASA's successes were once a source of national pride, too many people now find its problems a source of national embarrassment.

The budget available to NASA from 1975 to 1985 had less than half the purchasing power of the budget during the Apollo decade. Rather than adjust its goals and style of operation to this changed reality, NASA chose to stay on the roller coaster and wait for another Apollo-like surge of support. In all fairness to NASA, the lack of any outside demand for change would have made it difficult to do otherwise. But the result has been an organization that appears

Caught up in continued uncertainty over its place in the national scheme of things, NASA has understandably tried to build on the pattern of success established during Apollo.

to have lost its edge of technical and managerial excellence. As the Pulitzer-prize winning historian Walter McDougall asked, "How do you institutionalize charisma? As soon as you do it, you create a church or a bureaucracy or an economic system which gradually becomes stifling, and the charisma itself over the course of a generation or three dies away and all you have left is the . . . shell of what was once a great, expansive movement."[2]

Yale sociologist Gary Brewer has written perceptively of the consequences of NASA attempting to retain its Apollo-era identity in very changed circumstances. During the Apollo program, he suggests, NASA was a "perfect place," "the best organization human beings could create to accomplish selected goals." But in the absence of definitive goals, the lessons of success become "obsolete." In Brewer's view, the consequences of an organization continuing to try to maintain its self-image when that image does not match reality are "flawed decision-making, self-deception, introversion, and diminished curiosity about the world outside the perfect place." Correcting this situation requires "new ways of thinking, new people, and new means to come to terms and cope with" a changed environment.[3] Making this kind of correction is at the heart of the changes now underway.



a long and often exciting ride....

A prescription for change

Articulating the need for "new ways of thinking, new people, and new means" is a lot easier than coming forward with specific, broadly acceptable proposals for change. It is not surprising, therefore, that the process of programmatic reconstruction and institutional reform is not happening overnight; the system may have run out of forward momentum, but it certainly has a lot of inertia. Both Congress and the White House are now pushing hard for reform, however, and this pressure ultimately is likely to be irresistible.

Planning a program that requires more resources than are likely to be available is a recipe for frustration and failure. But that is the approach NASA has been following.

The most comprehensive diagnosis of the problems of the civilian space program and suggestions for change can be found in the December 1990 *Report of the Advisory Committee on the Future of the U.S. Space Program*, generally known as the Augustine report after the committee's head, Norman R. Augustine, chairman and chief executive of the Martin Marietta Corporation. The Augustine report—a politely worded but thorough critique of the way the United States has "done space" over the past two decades—is a compendium of suggestions for a new approach to the space program. Most of those suggestions make eminent sense. The report's central message is that expectations for the civilian space program must be reduced to match the priority and resources likely to be provided by the political system. Continuing to plan and to try to execute a program that requires more resources than are likely to be available is a recipe for frustration and failure. But that is the approach NASA has been following.

The Augustine report makes this point most strongly in discussing plans for human exploration beyond Earth orbit. The committee recommended that exploration be put on a "go as you pay" basis, which in the current budget environment means a slow-paced effort for at least the next few years.

Yet to most people, exploration is what the space program is about. Without the sense that new worlds are being visited and that humans someday will be born, live and work, and die in places other than Earth, much of the spirit would go out of the U.S. space program, and with it the program's value as a symbol of future possibilities. Even though the goal of human exploration of the solar system may be inappropriate as the focal point for rebuilding a viable space program over the next few years, it ought to be maintained as the long-range purpose of putting humans into space and the top-priority objective shaping the space station program. Indeed, in this sense the United States *is* spending lots of money on space exploration in the 1990s, as it develops Space Station Freedom: If we do not intend to journey beyond Earth orbit in the first quarter of the next century, the station is really not a very good investment.

Following the recommendations of the Augustine report, NASA has created a high-level Office of Exploration, but Congress has so far been unwilling to grant it any significant resources. Another advisory committee, the Synthesis Group, last summer recommended the creation of a national program office

for exploration, with NASA at its center but also involving the Department of Energy and the Department of Defense. This ought to be done, but it will not amount to much unless additional funds are made available for investing in enabling technology, necessary life sciences research, continued study of mission alternatives, and some visible but low-cost robotic missions to lay the foundation for the future. The recommendation that we "go as we pay" is sound, but it is essential that there be a sense that we are sometime going to go.

In addition to exploration, the other widely understood and broadly supported objective of the civilian space program has been the expansion of knowledge—that is, science. The support of fundamental science is an accepted government mission in the United States, and NASA's space science program represents some 15 percent of federal spending on basic research. The fiscal year 1992 budget of NASA's Office of Space Science and Applications is $2.7 billion, almost as much as the total budget of the National Science Foundation; actual costs of space science are considerably higher, as the OSSA budget does not include the substantial costs of launching science missions.

The Augustine report recommended ensuring adequate funding for the core NASA science program before undertaking other areas of space activity. The committee suggested that the space science program should receive approximately 20 percent of the overall NASA budget. It is not clear that this recommendation is in the best interest of anyone except the space science community. Space science not linked to exploration may be of high intellectual content, but it is less likely than many other areas of fundamental research to yield applications of direct benefit on Earth, and it is very expensive. In a time of tight resources, it is questionable whether the country should fund all of the science missions being advocated by the space science community.

Most priority setting for space science is not closely coupled with national research priorities. It is fair to ask how much could stand rigorous comparison with science done on Earth.

The historical purpose of the "20 percent for science" rule of thumb is to prevent funds being taken from the science program to support the high costs of developing and operating the systems for human spaceflight. But it also appears suspiciously like an entitlement within which NASA and the space science community are free to set their own priorities. With a few exceptions (particularly astronomy and astrophysics and perhaps Earth observation), priority setting for space science is not closely coupled with the increasing attempts to set overall national research priorities. It is fair to ask how much of the science done under NASA sponsorship could stand rigorous comparison, on the grounds of scientific merit, with science done on Earth; the answer is likely not to be very comforting to those who have made their careers doing science in space. Getting the space science program in balance with both overall scientific goals and the budgets likely to be available is an important element of revising the civilian space program.

There are signs that this is happening. Last summer was a sobering experience for the space science community. Although other factors were at play, the June 1991 House floor vote on the NASA appropriation was portrayed by many as a choice between funding space science and funding Space Station Freedom, and the vote went strongly in favor of the station. Then the Senate

warned NASA not to expect significant growth in future budgets and that any major new starts in the NASA program would come under intense scrutiny.

In response to these indications of a changed future environment, the space science community inside and outside of NASA—much to its credit—has begun to reduce its future aspirations. Plans for the science program for the rest of the decade are emphasizing smaller, less expensive missions. This is precisely the kind of change recommended by the Augustine report; it is encouraging to see that at least one portion of the space community has heard the message and is moving to adjust its strategy to future realities.

Much potential lies in the application of space technology to high-priority public concerns, such as global environmental change and U.S. competitiveness.

In addition to exploration and space science, space proponents frequently cite a third goal for the space program: technological and commercial growth. One by-product of NASA's early history as an instrument of international political competition is that the agency historically has not had to give much attention to producing tangible benefits for those who pay its costs. Yet much potential lies in the application of space technology to high-priority public concerns, such as global environmental change and U.S. competitiveness. NASA has little tradition of planning and executing programs aimed at applying scientific discoveries and technological innovations to concrete human concerns; NASA's focus has been on exploring the heavens, not on helping the Earth.

Making the space program relevant to important human concerns seems the most likely way to give it staying power. Again, NASA seems to be heading in this direction, particularly with its set of Earth observation programs collectively known as Mission to Planet Earth. Until recently, the centerpiece of the Mission to Planet Earth effort was a planned series of large, expensive, multi-instrument platforms known as the Earth Observation System. This approach to measuring global change did not win the support of the environmental science community outside of NASA, and the agency has recently bowed to external pressure and changed its plans to encompass smaller, more focused missions, with an early emphasis on pressing environmental concerns rather than long-term scientific questions. Here again, the willingness of the space agency to adjust its plans is commendable.

NASA has an Office of Commercial Programs that has been conducting what amounts to an industrial policy for space without drawing fire from the free-market advocates in the Reagan and Bush administrations. A major reason may be that few outside (or inside) NASA take the program seriously; one scientist recently described the office's approach as "firing a shotgun into the air and hoping that some geese fly over." But space development could produce commercial payoffs. NASA should give higher priority to collaborating with the private sector to develop the capabilities for applied experimentation and supporting the generic research needed to explore promising possibilities.

Of all the elements of NASA, it is those associated with developing and operating the large and expensive systems for human spaceflight that are proving the most resistant to change. This is not surprising; it is in these portions of the agency that the successful experience of Apollo is most cherished. It is also in these parts of NASA that inertia is highest, given the numbers of people involved and the size of the individual programs.

Change is not easy to effect, but change will have to come if NASA is to regain its reputation as a "perfect place." The emerging generation of NASA leaders has not been shaped by post-Apollo attempts to pretend that nothing fundamental had changed. As these people take charge, and as the science and applications parts of NASA adjust to changed realities, it is reasonable to expect more shifts in NASA's overall operating style.

Re-creating the institution

The key to reconstructing the civilian space program is *not* imposed organizational change *per se*. Rather, the key is forming a consensus on a set of space activities for the next decade that commands broad support among knowledgeable people, is in balance with the priority of the space program in the overall national scheme, and can be carried out with the resources likely to be made available. Then an organization well-suited to carrying out those activities can be put in place.

What is needed is to re-create an institution for the rethought space missions of the future—one that draws primarily, but not necessarily exclusively, on the base that NASA provides.

This new set of activities must certainly be less ambitious than the one currently at the core of NASA's planning. As the contributions of space are assessed against global realities and national priorities, those in charge of space programs all around the world are having to reduce their aspirations from the ambitious proposals of the early 1980s. The United States is part of this overall movement to a more temperate approach to civilian space programs.

It is often forgotten that NASA was created in the years from 1958 to 1961 as an institution to carry out a particular set of missions. This institution carries with it a history of many successes and a few failures; it also represents a remarkable reservoir of talent dedicated to space achievement. What is needed is to *re-create* an institution for the rethought space missions of the 1990s and the next century—an institution that draws primarily, but not necessarily exclusively, on the base that NASA provides.

Change is never easy, and changing what has given the country and the world the remarkable shared experiences of humans walking on the moon, spacecraft flying past other planets, and astronauts smoothly landing their craft on return from orbit risks losing something that has been very important to many. But if the nation is to have a space program worth the costs and risks involved, additional change is absolutely necessary. So is some degree of patience, as a new space program for the United States is put in place. •

1. For an account of the Kennedy decision, see John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, Massachusetts: MIT Press, 1970).

2. McDougall's comment can be found in John M. Logsdon et al., *Apollo in Its Historical Context* (Washington, D.C.: Space Policy Institute, George Washington University, 1990), p. 40.

3. Gary D. Brewer, "Perfect Places: NASA as an Idealized Institution," in *Space Policy Reconsidered*, ed. Radford Byerly, Jr. (Boulder, Colorado: Westview Press, 1989), pp. 158-159.

Kevin Tansey & Rosa Johnson

THE PENTAGON'S DEPENDENCE ON FOREIGN SOURCES

When so much of the "smarts" in our smart weapons comes from abroad, is there cause for concern?

AMERICANS CAN TAKE pride in their country's conduct of the Persian Gulf War. After all the billions of dollars pumped into U.S. defense over the past decade, it was gratifying to see U.S. leaders, troops, and equipment performing so well. Our high-tech weapons were particularly impressive: Who will forget those televised images of the smart bombs' pinpoint accuracy?

Yet some of the wonder those images inspired turns to unease when one realizes that the "smarts" in many U.S. smart weapons were provided by foreign components and technology. For instance, the Tomahawk cruise missiles that hit Baghdad, the Patriot missiles that intercepted Iraqi Scuds, and the High-Speed Anti-Radiation Missiles (HARM) that damaged Iraqi radars all contained a small but crucial ceramic part made by Kyocera Corporation of Japan.[1]

And this is only one example. U.S. weapon systems contain a great many critical components manufactured offshore.[2] In recent years, the Department of Defense (DOD) has increased its reliance on Japanese suppliers for high-speed transistors, ceramic packages, laser diodes, and some high-speed logic and memory chips. The most complex parts of the Sparrow air-to-air missile, to name one system, are made overseas; the guidance system contains circuits from Japan, and a critical memory chip is made in Thailand.[3] Foreign sources such as these may offer lower-cost or higher-quality products than domestic firms—or there may simply be no domestic source available. And relying on foreign suppliers in this manner may be perfectly acceptable, even advantageous.

But if no domestic source exists for these items, the foreign suppliers could someday prove unreliable in ways that compromise national security. At the very least, foreign companies may not respond as rapidly to "rush" orders as this country would like, particularly during crisis situations. In fact, during the Persian Gulf War, there were reportedly occasions when the Bush administration had to appeal to foreign governments to prod firms in their countries to deliver crucial components on time.[4] The dependency issue has been raising increasing concerns about America's continuing ability to plan and provide for its defense needs on its own terms.

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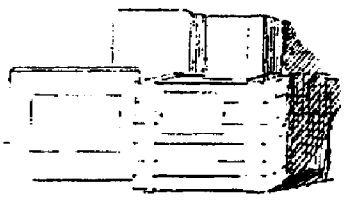
The extent of DOD's foreign dependence

Before one can assess the overall significance, including the risks to national security, of the U.S. military's dependencies on foreign suppliers for critical components of its weapon systems, one must determine how extensive such dependencies are. This is no easy task. Individual studies attempting to systematically identify such dependencies are time-consuming and difficult to complete, especially if the studies do not focus on critical components. A major reason for the difficulty of the studies is that an estimated 40 to 60 percent of the money DOD spends on weapon systems flows down into subcontracts. These subcontracts can be for major subsystems, such as the engine for an aircraft or tank; for components, such as an engine's compressor, combustor, or turbine; or for parts of such components. Consequently, the subcontracts can be awarded down through many levels or "tiers" of producers or suppliers—sometimes as many as seven or eight. At any of these levels, items procured by DOD contractors and subcontractors may be supplied by foreign sources. If they are, and if there is no immediately available domestic item that can meet the defense requirement, a dependency exists.

To be systematic, this careful scrutiny needs to be applied to every critical subsystem, component, or part in a particular weapon. Because this is a huge undertaking, most studies of foreign dependence have examined only a handful of weapon systems.[5] The Navy and the Department of Commerce, for example, have been studying the Mark 48 torpedo, the HARM missile, and the Verdin communication system for more than four years. For these three systems alone, 10 contractors are considered to be at the first tier; more than 1,100 subcontractors have been identified at the second tier, more than 3,000 at the third tier, and more than 6,000 at the fourth tier. Preliminary results indicate that, at the fourth tier, the value of subcontracts awarded to foreign sources increased dramatically. For example, for one first-tier HARM contractor, subcontract awards to foreign sources were valued at $300,000 at the third tier but $300 million (25 percent of the value of the subcontracts) at the fourth tier.[6]

Defense Department officials just don't know the extent of foreign sourcing in their weapon systems—particularly at levels beyond the prime contractors and their immediate subcontractors.



Another study, conducted by the Joint Logistics Commanders, reviewed 13 DOD weapon systems, including the F-16 and F-18 aircraft, the Advanced Helicopter Improvement Program, the M-1 Tank, the AN/SSQ-53B Sonobuoy, and the Sparrow missile.[7] In eight of these systems, dependencies on foreign sources were found; in the six systems listed above, these dependencies were judged as having the potential to cause serious problems.

Recently, GAO examined whether foreign dependencies previously identified in the Joint Logistics Commanders' study still existed for selected items of the M-1 Abrams tank and the F/A-18 Hornet aircraft, two weapons used in the Persian Gulf War.[8] The GAO study determined that, in general, foreign dependencies still existed for the items reviewed, such as the F/A-18's ejection seat and, in the M-1 tank, certain optics and microcircuits important in aiming and firing the tank's main gun.

These and other reports only scratch the surface of the problem. At this time, however, it is impossible to know how deep the problem goes. DOD officials have little awareness of the extent of foreign sourcing or dependence in their weapon systems—particularly at levels beyond the prime contractors and their immediate subcontractors. And, at present, neither laws nor regulations generally require that they seek out this information.

The significance of foreign dependence

Not only does DOD have very limited information on foreign sourcing and dependencies of weapon components, it also has not established criteria for determining what levels of foreign dependence should not be tolerated for various items and what actions should be taken to reduce the associated risks. As a result, no one knows the extent of U.S. dependency on foreign sources, and no one has decided exactly which instances of dependency should be considered to have the potential to cause trouble.

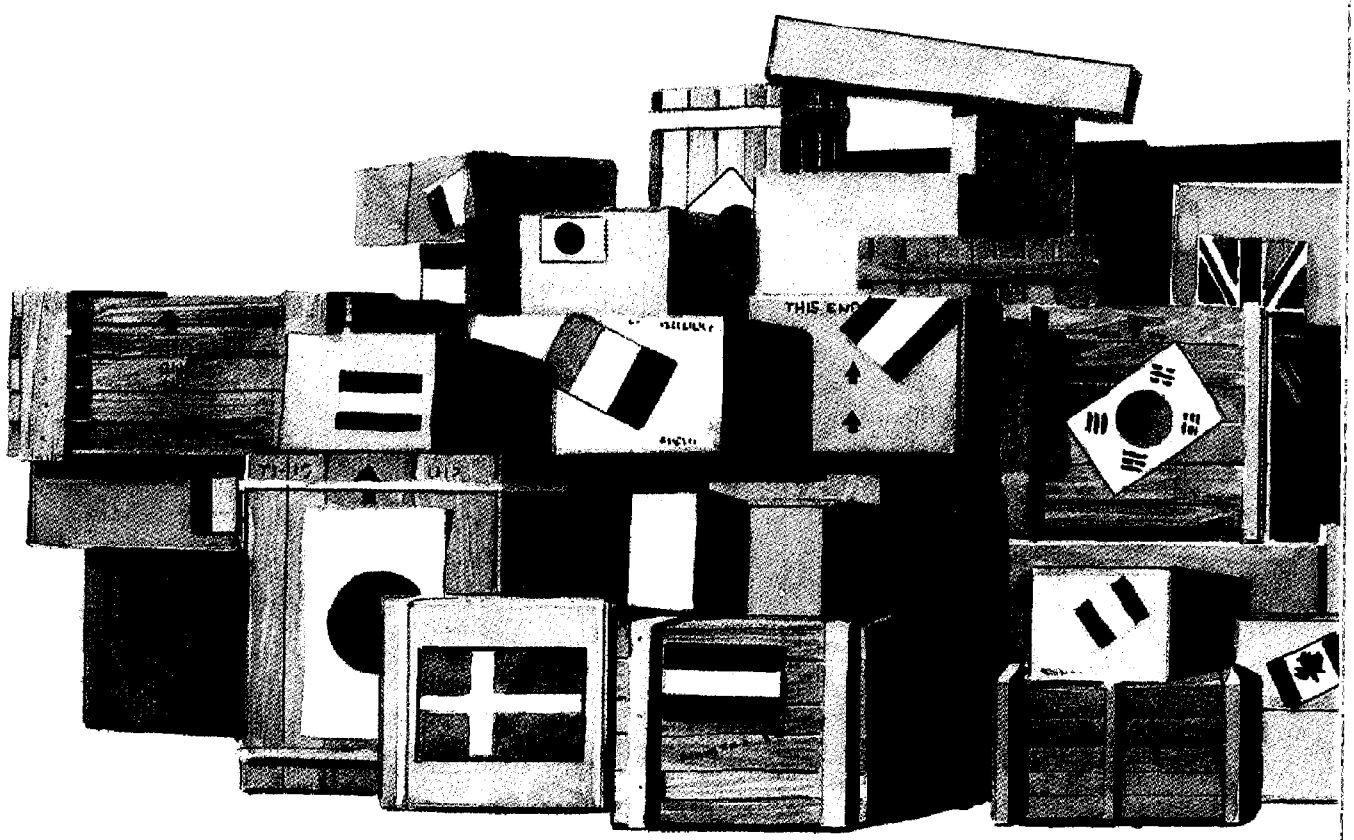
It is important to remind oneself that, in today's increasingly interdependent global economy,

foreign sources of technology and supplies are a fact of life. These sources may provide economic, military, and political advantages, including lower costs, better quality and performance, faster delivery time, and better integration of U.S. equipment with that of its allies.

On the other hand, one must also keep in mind the disadvantages that may result from foreign procurement. For one thing, there is always the possibility that foreign suppliers will prove less reliable than domestic ones, especially during such crises as the recent war. Such a lack of reliability could result from a variety of factors, including the supplier's distance from the United States, its proximity to potential battle sites, economic instability in the country where the supplier is located, and political differences between the supplier's country and the United States. For example, because of foreign policy differences between Japan and the United States during the Vietnam War, Sony would not supply a TV camera for missile mounting. Moreover, plants located offshore are beyond the reach of the Defense Production Act, which authorizes the federal government to require domestic facilities to give priority to production of items needed for defense.

Another potential disadvantage of dependencies on foreign sources is limitation of DOD's access to advanced technologies for developing future weapon systems. If foreign companies gain a greater and greater share of the market for weapon components, manufacturing moves offshore and control over technology development tends to follow. Such technological developments could be crucial to the qualitative superiority of future weapon systems. If the superiority of U.S. weaponry erodes, the nation's military edge in certain areas could be jeopardized.

Foreign sourcing and dependencies can also lead to a reduction in domestic production capability: If more and more DOD contracts go to overseas firms, U.S. manufacturers may not have sufficient demand to keep production lines open. As a result, the United States might increasingly lose the ability to produce critical components for its own weapon systems. In addition, U.S. businesses or industries will likely shrink or even fail, causing U.S. workers to lose their jobs; this could include workers with key technological expertise. And, to the extent that defense and commercial technology and production are related, a dropoff in domestic-based defense production can be expected to contribute to U.S. manufacturers' loss of competitive standing in commercial markets.

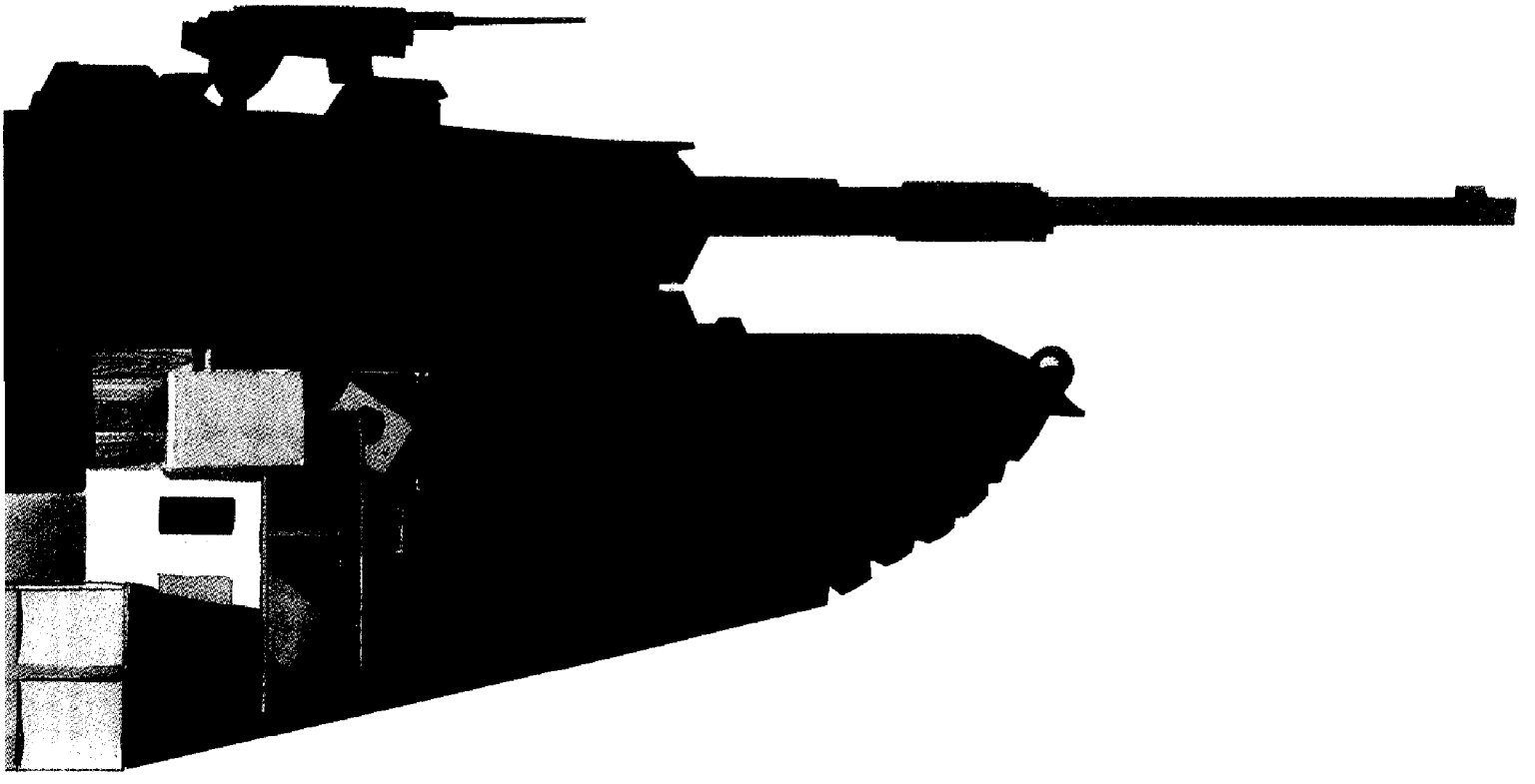


In general, one can say that a foreign dependency creates a serious risk when it compromises the nation's ability to produce a critical weapon system or to secure the most advanced technology for a future system. Some experts point out that the risks of foreign dependency are less if a particular component is available from several foreign sources, whose production facilities are located in nations that possess multinational perspectives and that follow relatively free trade policies.[9] The risks rise, however, if the component is available from only one country—particularly if that country dominates the technology in question and is able to dictate the terms on which the technology is traded. Therefore, when trying to determine whether a particular instance of foreign sourcing jeopardizes national security, one must consider the reliability of the foreign source or sources. Other factors that must be kept in mind include the extent to which domestic goods may be substituted for foreign-supplied goods, and how long it would take these domestic alternatives to become available; the importance to the overall defense mission of the item under consideration; and the likelihood that a war or other crisis will make the item of crucial importance.

Reducing the risks of foreign dependencies

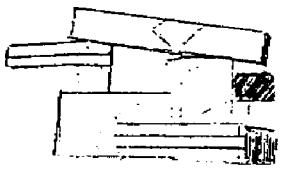
The Defense Department has made some efforts to address the general problem of foreign sourcing and dependencies. For example, in 1985 it started the Defense Industrial Network (DINET) project—a prototype defense industrial data base or information system. DINET is intended to provide information on important aspects of the defense industrial base, including foreign sources of supply at lower levels of subcontracting. But DINET has never been fully funded, and DOD acknowledges that it has many limitations.

Ad hoc studies of particular weapon systems (such as those, mentioned above, conducted by the Joint Logistics Commanders and the Navy and the Commerce Department) can be helpful in identifying foreign dependencies. But continued heavy reliance on such studies is not a workable alternative to a more comprehensive approach, because it does not put DOD in a position to take aggressive, forward-looking action. By their nature, such studies cannot provide the needed



visibility into the extent of the problem of foreign dependencies at the lower subcontracting levels, even though it is precisely at these levels that domestic U.S. industries face a significant decline in competitiveness.

Another DOD effort now under way involves the revision of DOD's acquisition and industrial preparedness regulations and procedures. The revisions are intended to require program managers responsible for acquiring weapons to assess, starting from the early stages of the acquisition process, the ability of the U.S. defense industrial base to meet potential production requirements. This explicitly includes consideration of foreign sourcing and foreign dependencies. Historically, however, there has been a separation of the processes for industrial preparedness planning and weapons acquisition within DOD; without assistance from industrial preparedness planning officials, program managers may lack the expertise to make assessments about the U.S. industrial base and foreign dependencies. For these and other reasons, without an effective information system, it is not likely that the regulatory and procedural revisions will result in an overall identification of the extent of foreign dependencies that exist for critical weapon components.



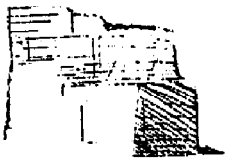
Various actions could be taken to reduce the risks of foreign dependencies. Some would involve broad policy decisions on such matters as tax incentives and anti-trust laws.

Various actions could be taken to try to reduce the risks that may arise from foreign dependencies. Some of the possible actions involve broad policy decisions relating to such matters as tax incentives and antitrust laws. For example, the National Cooperative Research Act of 1984 modified the antitrust laws covering cooperative research and development to permit firms to share costs, eliminate duplicate efforts, and reduce the time needed for technology and product development. These provisions are intended to improve U.S. economic competitiveness by helping U.S. firms regain their technological edge in certain areas, thereby reducing U.S. dependencies and national security vulnerabilities.

One such initiative, launched in 1987, is SEMATECH—a government-industry consortium to develop semiconductor technology. SEMATECH was a response to a dramatic drop in the U.S. semiconductor industry's international leadership position. This type of government-industry collaboration, with governments contributing millions of dollars of investment, is seen by some as a major factor in the success of Japanese and European firms against which U.S. firms find themselves competing.

A variety of other approaches could also be taken to reduce the risks that may be caused by foreign dependencies:

- The federal government could stockpile critical foreign-sourced components, including goods in process, just as it now stockpiles raw materials. This approach is not without disadvantages, however: Not only could the costs be high but, as technology advances, the components could become obsolete.
- The federal government could fund the establishment of its own plants to produce items now purchased abroad. Again, the disadvantage in many cases would be the considerable cost; because most items from foreign sources are acquired in relatively small quantities, these new facilities might not be very cost-effective.
- The federal government could fund additional research and development and create additional privately owned and operated facilities to produce the weapon components. Like the previous option, this option could be criticized because of potential inefficiency.
- Where feasible, the government could substitute domestically purchased items for those that are foreign-purchased. The problem here is that the domestic substitutes would be unlikely to offer all the same advantages in performance, quality, delivery time, or cost; in some cases, this may be unacceptable. Also, protectionism for domestic industries or firms is not noted for stimulating them to invest and become internationally competitive.
- DOD could fund redesign work, where necessary, so that components available in the United States but not now substitutable could be substituted for components available only overseas. This approach would work only if it did not involve an unacceptable reduction in weapon quality or performance and if the difficulty or cost of redesign were not excessive.
- In a variant of the previous two options, DOD could, wherever possible, initially establish its requirements for weapons on the basis of what is available through U.S. industry and technology. Again, primary disadvantages might be reduced weapon performance or reliability, increased cost, and a lack of international competitiveness because of protectionism.
- The federal government could fund the licensing of domestic firms to manufacture items developed and designed by foreign firms. But this



The problem of foreign dependence in defense-related items does not exist in a vacuum. A central challenge for the United States is to meet military requirements in such a way as to build a stronger, more internationally competitive civilian economy.

approach faces several hurdles: The foreign firms might be unwilling to license their products to domestic manufacturers; the U.S. government might have to pay steep licensing fees; and the domestic firms might not always be able to maintain the desired level of quality.

• The federal government could restrict the import of certain items that are deemed to constitute a threat to national security. Such restrictions are in fact allowed under current law. They have already been placed on antifriction bearings, machine tools, and plastic injection molding machinery. Problems might arise, however, if import restrictions triggered retaliatory protectionist actions by other countries.

Although we have focused on the potential drawbacks of these approaches, options such as these need to be considered in cases where foreign dependencies for critical weapon components are judged to pose unacceptable risks to national security. No one option will make sense in every such case. Instead, the pros and cons need to be considered on a case-by-case basis. To perform such analyses intelligently, however, the federal government needs a much more comprehensive understanding of the extent to which U.S. weapon systems depend on foreign components. This understanding will not be possible until DOD designs and implements an effective information system detailing this dependence, as well as a set of criteria for determining how much foreign dependence can be tolerated in various cases.

The international economy

The problem of foreign dependence in defense-related items does not exist in a vacuum. Because of increasing competition in the global marketplace, the U.S. economy as a whole has come to rely more and more on foreign products, components, and technology. Furthermore, the industrial and technological base of the commercial sector is increasingly important to defense. Particularly as one examines the lower levels of DOD subcontractors, one finds that defense needs are often met by firms that primarily do commercial rather than defense-related work.

Consequently, this country's ability to meet its defense needs is increasingly tied to the strength of the U.S. economy and its ability to compete internationally. Unfortunately, there are signs that, in the race for world leadership in key technologies, the United States is slipping badly. U.S. industry has often failed to rapidly and effectively commercialize the results of American technological advances by successfully introducing products into the marketplace. Furthermore, out of 12 crucial emerging technologies identified by the Commerce Department and projected to account for nearly $1 trillion annually in sales on the world market by the year 2000, the United States is expected to lag behind Japan in most cases and behind Europe in several.[10] Most of these emerging technologies are dual-use, having important commercial *and* military applications. These trends do not bode well either for foreign dependencies or for U.S. technological leadership, jobs, and long-term productivity growth.

A central challenge for U.S. policymakers and for U.S. industry is to meet military requirements in such a way as to build a stronger, more internationally competitive civilian economy. Not only will such an economy contribute to the broader aspects of American strength and security, but it will also be better equipped to satisfy this nation's defense needs. •

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1. Jacob M. Schlesinger, "Kyocera's Ambivalent Role in Weapons," *Wall Street Journal*, Feb. 5, 1991, p. A-19.

2. In this article, "offshore" or "foreign" source means a source of supply, manufacture, or technology located outside the United States and Canada.

3. Paul Magnusson et al., "American Smart Bombs, Foreign Brains," *Business Week*, March 4, 1991, p. 18.

4. Stuart Auerbach, "U.S. Relied on Foreign-Made Parts for Weapons," *Washington Post*, March 25, 1991, pp. A-1 and A-17.

5. DOD contracts for more than 100 major weapon systems as well as numerous other weapons.

6. Interview with John Tucker, Office of Industrial Resources, Department of Commerce, April 26, 1990; and telephone interview with Brian Nilsson of the same office, April 8, 1991.

7. *A Study of the Effect of Foreign Dependency* by DOD's Joint Logistics Commanders (Feb. 15, 1986). Major portions of this report are classified.

8. *Industrial Base: Significance of DOD's Foreign Dependency* (GAO/NSIAD-91-93, Jan. 10, 1991). This report was issued less than a week before the Gulf War began.

9. Theodore H. Moran, "The Globalization of America's Defense Industries: Managing the Threat of Foreign Dependence," *International Security*, Summer 1990, Vol. 15, No. 1. Also see *A Strategy for Strengthening the National Defense: The Role of Its Industrial Base*, a "draft final" report by the Defense Manufacturing Board Critical Industries Task Force, Jan. 23, 1990; and *Foreign Vulnerability of Critical Industries*, a report by the Analytic Sciences Corporation (TASC), March 1, 1990.

10. U.S. Department of Commerce, Technology Administration, *Emerging Technologies: A Survey of Technical and Economic Opportunities*, Spring 1990.

John E. Watson & Thomas W. Hopp

THE PRIVATE SECTOR'S EXPERIENCE WITH TOTAL QUALITY MANAGEMENT

U.S. companies are learning that quality pays dividends.

XEROX, THE COMPANY that created the copier industry—the company whose name is *synonymous* with plain-paper copying—faced a tough challenge during the 1970s. As Japanese copiers of comparable quality and lower price were shipped into North America, Xerox's share of the North American market plunged from 93 percent to 40 percent.

Ford Motor Company was having similar problems. Between 1978 and 1982, its U.S. sales of cars and trucks fell by 49 percent, resulting in a cumulative operating loss of more than $3 billion.

Around this same time, Milliken & Company—a privately owned textile manufacturer long recognized for quality products and its state-of-the-art technology—began to ask why some of its Japanese competitors achieved higher quality, less waste, greater productivity, and fewer customer complaints, even though they used technology less advanced than Milliken's. The reasons, company executives found, lay in management approaches and personnel practices that drive improvements in quality and efficiency.

Milliken, Ford, and Xerox have since adopted such practices. The results? Since the early 1980s, Milliken's productivity has increased 42 percent and sales have risen significantly. Between 1981 and 1989, Ford's market share rose from 16.3 percent to 22.4 percent; the company moved from a net loss of $1 billion to a net profit of $4 billion. And Xerox has recaptured its leadership in document processing technologies.

These companies' experiences are not unique. In recent years, a number of U.S. companies have found that they could not sufficiently raise their standards of quality by using conventional approaches to managing product and service quality. Instead, like Xerox, Ford, and Milliken, they have adopted a new management approach known as "total quality management" (TQM).

Traditionally, management has sought to ensure quality through inspection at the final stages of production, just before the product or service is

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made available to the customer. This approach, referred to as "inspecting in" quality, puts responsibility in the hands of quality control experts.

The TQM approach, on the other hand, calls for management practices that "build in" quality throughout the process of creating a product or service. Quality then becomes the responsibility not just of quality control experts but of every employee. How quality is defined depends wholly on the customer: A quality product or service is one that always meets the customer's expectations and needs. TQM emphasizes that true quality requires the full involvement of the entire work force and that managers and workers must seek continually to improve the work process. In other words, TQM is not a destination but a journey.

TQM in U.S. corporations

Despite the apparent success of many companies that have implemented TQM, some observers harbor doubts about it. TQM may have been the main driving force behind Japan's economic success over the past several decades; but because it has been most widely applied in Japanese culture, these skeptics say, it is not likely to be effective in an American context. How much weight should such criticisms be given?

GAO recently investigated the impact of TQM practices on the performance of 20 U.S. companies.[1] The results of this study (the first to gather empirical rather than merely anecdotal evidence) showed that the myth about TQM not being applicable in the United States is just that—a myth. Most companies GAO studied experienced an overall improvement in corporate performance. For example, on an average annual basis, these companies had an 11.6 percent drop in customer complaints, a 12 percent reduction in order-processing time, a 10.3 percent decline in defects, and a 16.6 percent increase in the volume of employee suggestions. Overall, the companies boosted their market shares by 13.7 percent.

Essential features of TQM

Total quality management is not a cookbook approach; it cannot be boiled down to a series of clear-cut steps. A company pursuing TQM generally considers the ideas of a number of quality practitioners—particularly W. Edwards Deming, Joseph M. Juran, Armand V. Feigenbaum, and Philip B. Crosby—and then develops a TQM approach that suits its own unique work environment and management problems.

At the same time, TQM is not just a catchall term for any type of management reform. A consensus has emerged as to the essential elements of any TQM approach. Those organizations in GAO's study that experienced improved performance under TQM tended to have implemented most if not all of these elements.

Focus on the customer

Customer satisfaction is critical to competitiveness. Because TQM treats customers as the driving force behind all quality efforts, organizations must determine customers' needs and then must put processes in place to fulfill them.

For instance, in 1984, Goodyear Tire & Rubber established a customer support network based on a toll-free number. USAA Property and Casualty insurance division conducts quarterly customer attitude surveys and evaluates its service delivery against the standard set by L.L. Bean. And the Business Products and Services division of Xerox analyzes a wide variety of data, gathered from monthly surveys of 55,000 Xerox equipment owners, to identify customer requirements. This information is then used to develop concrete business plans for making the necessary improvements. Along with other steps Xerox has taken, this focus on customer satisfaction has contributed to some impressive statistics: Between 1983 and 1989, there was a 38 percent increase in the number of customers for copier/duplication systems who considered themselves "highly satisfied" and a 60 percent decrease in customer complaints.

Active top leadership

The top executive of an organization must provide active leadership if quality is be established as a fundamental value in the company's management philosophy. In the organizations GAO studied, quality concepts were clearly articulated and thoroughly integrated throughout all organizational activities. Top executives also took the lead in establishing a more flexible and responsive corporate culture to allow for more communication—both formal and informal—between departments and among workers.

At Milliken, for example, the TQM process began in 1981 when a program called Pursuit of Excellence (POE) was launched by senior management. Today, Roger Milliken, chief executive officer, and Thomas J. Malone, chief operating officer, devote more than half their time to POE. Similarly, Xerox's TQM drive, known as "Leadership Through Quality," was announced in 1981 by then Chief Executive Officer David Kearns. Management has continued to demonstrate leadership through daily practice by frequent communications that keep all Xerox employees informed of the progress of Leadership Through Quality.

Employee involvement and empowerment

In order to strengthen employee commitment to continuous quality improvement, organizations in GAO's study focused on teamwork and on increasing employees' sense of involvement and empowerment. Companies also provided training to ensure that employees had the skills necessary for a TQM approach.

Motorola, for example, encourages first-line employees to make significant on-the-job decisions. To help prepare them for these responsibilities, the company spends more than $100 million annually on training and education—an effort known as "Motorola University."

At Milliken, teams of workers are a hallmark of the quality process. Production work teams can undertake training, schedule work, and establish individual performance objectives. Moreover, any Milliken employee can halt a production process if

he or she detects a quality or safety problem.

Xerox's approach to quality issues is reflected in the company's concept of "Team Xerox." In 1988, teams in manufacturing and development were credited with saving $116 million by reducing scrap, tightening production schedules, and devising other quality-enhancing measures. Xerox provides quality training to every employee, and the company gives rewards and recognition for quality improvement efforts not only to individuals but also to groups.

Actions based on facts

Fact-based decision-making is another common feature of TQM. In order to determine when changes are needed, companies use systematic processes to continually measure and evaluate the quality achieved with current production processes. TQM practitioners refer to this as a "Plan-Do-Check-Act" approach to quality improvement.

At Milliken, for example, quality improvement efforts are founded on factual information contained in databases accessible from all Milliken facilities. Xerox has identified its most important business processes and compared its performance in these areas with world-class standards to establish benchmarks. Employees are encouraged to use these benchmarks to assess their work.

Partnership with suppliers

Traditionally, U.S. firms have established minimum specifications for suppliers and then, from the pool that met those minimum standards, chosen the suppliers that offered the lowest prices. Under TQM, many companies instead have established closer, long-term partnerships with a smaller number of suppliers who meet higher quality standards. Such suppliers, it is felt, can be enlisted as full partners in an organization's own quality efforts.

In certain cases, companies have included their suppliers in key product design meetings. Some companies have even gone so far as to help suppliers improve their own quality systems. Milliken, for instance, has provided training in quality principles to its suppliers as well as to its own employees. Xerox's suppliers receive training in such areas as statistical process control and total quality techniques. These suppliers credit Xerox with improving their products and operations; over the past five years, the number of defective parts from suppliers has been reduced by 73 percent.

TQM's broad applicability

Although TQM principles were first applied in manufacturing companies, the approach is flexible enough that many different kinds of organizations can benefit from putting it into practice. The private-sector organizations in GAO's study included both manufacturing and service companies (such as insurance, telephone, and catalog sales companies), both large companies and companies with fewer than 500 employees. Companies in every category improved their performance with TQM.

For example, not only did a TQM approach help Corning greatly improve the quality of output in its manufacturing plants, it also spurred improved operations in its corporate tax unit. That unit simply applied the principle of finding out its

customer's needs. In this case, the customer was the Internal Revenue Service, which turned out *not* to want a summary of thousands of accounts detailing the expenses of Corning's various departments. The resulting change in procedure reportedly saved Corning 400 hours of personnel time annually; the IRS also saved the hundreds of hours it had previously spent unraveling the accounts summary.

Motorola had a similar experience in one of its staff offices. The internal audit department achieved a 26 percent increase in audit staff productivity, thereby saving $1.5 million. In addition, the time required by external auditors to complete their review was cut in half, resulting in a savings of $1.8 million.

TQM can also yield benefits in the country's largest service organization—the federal government. Many federal executives, managers, and employees have realized the need to do business in a new way and have made a commitment to TQM principles. The potential benefits include billions of dollars in savings, more efficient and effective government, and increased citizen satisfaction with the services they receive.

Reaping the benefits

Wherever TQM is applied, it is crucial that the organization implementing it allow sufficient time for results to be achieved. For the companies in the GAO study, it took anywhere from one to five years for the initial benefits of TQM to be realized; the average was two and a half years. TQM is not a means of improving performance in the short term. It takes time to change a corporate culture, plan new strategies, and train people in new ways of thinking and working. Most importantly, it requires continuous hands-on leadership.

With the right leadership and enough time, the benefits of TQM can be enormous. Not only will individual organizations improve their performance, but the U.S. economy as a whole will be strengthened. TQM's emphasis on quality and customer service can help U.S. private-sector firms to become more competitive in today's international economy and can help government organizations deliver services more efficiently, even in the face of budgetary and other resource constraints. Furthermore, the "second-best" product image that private-sector U.S. firms have had as compared with the Japanese has been helped by improvements in the quality of their performance (rather than by mere polishing of their corporate images). Similarly, the U.S. taxpayers' doubts about their government's ability to serve the needs of its citizens can be alleviated by an improved delivery of services. In other words, TQM can—if truly adopted as a fundamental change in approach—help an organization get the most out of what it has. •

1. See *Management Practices: U.S. Companies Improve Performance Through Quality Efforts* (GAO/NSIAD-91-190, May 2, 1991). GAO studied 20 companies that, in 1988 and 1989, were among the highest-scoring applicants for the Malcolm Baldrige National Quality Award—an award presented annually by the U.S. Department of Commerce's National Institute of Standards and Technology. The award recognizes companies that have successfully implemented total quality management systems.

Mary R. Hamilton, Allan I. Mendelowitz, & Richard L. Fogel

TQM at GAO

How—and why—the General Accounting Office plans to change the way it works.

THE U.S. GENERAL Accounting Office is adopting a new agencywide management system—a version of total quality management (TQM) specifically adapted to the character and mission of GAO. Experts have visited GAO to explain quality management and the ways in which other organizations have made it work; a GAO Quality Council meets regularly to determine how to make it work here; and pilot projects have been under way since the fall of 1990 in two GAO divisions. And in November 1991, GAO adopted a plan to guide the first two years' implementation of quality management in the agency.[1]

Change on this scale takes time, effort, and commitment. But GAO already produces high-quality products, enjoys a superb reputation, and attracts and retains some of the best people in government. So why should it turn to a new management approach?

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The basis of this decision lies in GAO's observation of the private sector. Recently, in response to a congressional request, GAO studied the adoption of quality management in private-sector companies.[2] As GAO staff visited these organizations and met with their managers and employees, they saw that these companies had significantly increased productivity and raised the quality of products and services, without hiring more people or spending more money. (Please see the accompanying article, "The Private Sector's Experience with Total Quality Management," written by John E. Watson and Thomas W. Hopp.) In addition, the companies enjoyed revitalized organizational cultures that drew on the skills and abilities of all their employees. The more GAO learned about their experiences, the more interested GAO became in trying quality management here.

THE MORE GAO LEARNED ABOUT THE EXPERIENCES OF PRIVATE-SECTOR COMPANIES ADOPTING TQM, THE MORE INTERESTED GAO BECAME IN TRYING QUALITY MANAGEMENT HERE.

GAO, of course, is a government agency, not a private-sector company. But that may be all the more reason for it to explore promising new management technologies. GAO recognizes its obligation to the taxpayers to get the most out of its resources. This need is especially potent at a time when GAO must respond to more congressional requests than ever before, while the size of its work force remains fairly constant.

We at GAO have worked hard in recent years to improve our efficiency while maintaining our quality, and we have made progress. We recognize, however, that in order to keep up with our responsibilities and ensure high-quality products—all without hiring more people—we will have to take a new approach to our work. Those who have been involved in the new effort so far feel that GAO has a chance not just to improve its own performance, but also to help demonstrate the practicality of this new approach to other government organizations.

A complete approach

GAO has undertaken many efforts in the past to increase its efficiency. What makes quality management different?

To begin with, past efforts to improve operations have not been systematic. We at GAO have always been good at identifying problems, but we tend to jump too eagerly to solutions. Those solutions, however, may not solve the underlying causes of the problems.

Quality management is far more comprehensive than most earlier initiatives. It requires the involvement and commitment of the full GAO work force. And it is based on a management concept that has proven its validity in organizations across the world: Give employees an understanding of their customers' needs, a culture that recognizes the employees' ability and worth, and the power to improve their way of working, and they will accomplish tremendous things for their organization.

UNDER THE TQM APPROACH, MANAGEMENT'S LONG-TERM RESPONSIBILITY IS TO CREATE AN ENVIRONMENT IN WHICH EVERY EMPLOYEE CAN CONTRIBUTE.

Under quality management, the never-ending quest for improvement becomes the primary goal of everyone in the organization. The process begins with top leaders, but it does not stop with them. Management's long-term responsibility is to create an environment in which every employee can contribute to the quality effort.

First, management must define a clear and constant vision of where the organization is going—complete with specific goals—and communicate that vision to the entire organization. The next step is to give all employees the training they need to enable them to carry out that vision. Once employees understand their roles in the total effort and have the skills to perform those roles, management then gives them the authority to do it. That means encouraging all employees to apply their own talents and ideas to improving the organization.

This approach rests on the idea that problems are caused not by people, but by flawed processes. An individual's performance can be only as effective as the procedures that govern his or her work. Because the people who actually do a job know the most about the way it is done, managers must give the employees themselves the power to improve the procedures that limit performance.

GAO's Vision, Mission, and Guiding Principles

Vision
We aspire to be the world's leading organization engaged in audit, evaluation, and public policy analysis.

Mission
We seek to achieve honest, efficient management and full accountability throughout government. We serve the public interest by providing members of Congress and others who make policy with accurate information, unbiased analysis, and objective recommendations on how best to use public resources in support of the security and well-being of the American people.

Guiding Principles
Commitment to quality is the single most important principle governing our work. We define quality as work that is:

- objective and independently derived,
- accurate, timely, and meaningful, and
- presented in a way that is most useful to responsible officials.

We value our people and the diversity they bring. We are committed to continuing self-examination to achieve organizational, procedural, and individual improvement.

Because TQM requires that people at all levels play a role, making continuous improvement a way of life at GAO means working both from the top down and from the bottom up. During the past year, GAO has done some of both. In April 1991, GAO established a Quality Council of leaders in the agency, chaired by the Comptroller General. These managers, working with people from every part of the agency, developed a detailed plan for launching quality management at GAO. At the same time, the two units involved in pilot projects trained their managers and executives, established teams consisting of staff from all levels, and trained team leaders.

Together, these actions have helped pave the way for GAO to implement quality management agencywide. Until now, most of the training, discussion, and planning has involved a relatively small number of people—most of them managers. As the new plan takes effect, GAO can begin to bring everyone into the effort.

Planning for quality

The newly adopted plan sets out steps for a two-year period ending November 1993—the first stage in a longer process. It begins by stating GAO's vision (where the organization is headed) and its mission (the "business" GAO is in). It also sets forth guiding principles to help all of GAO's people focus their efforts. (These statements and principles appear in the accompanying box.)

The plan then describes three major goals for the next two years. These goals include surveying GAO's customers, improving certain key processes, and establishing an organizational structure

that will allow GAO's quality management effort to involve more units and employees. The first two goals are primarily "top-down" efforts. The third will lay the groundwork for "bottom-up" activities to occur across the agency.

Goal 1: Determine our customers' needs

One of the first things we at GAO need to do is to determine the needs of our customers, by which we mean anyone, inside or outside of the agency, who uses or is affected by GAO's products and services.

BETTER PROCESSES MEAN BETTER PRODUCTS, SO EXAMINING THE WAY WE WORK WILL HELP US SERVE OUR CUSTOMERS EVEN AS IT MAKES GAO A MORE PRODUCTIVE AND REWARDING WORKPLACE.

Because our customers' requirements help define just what we mean by "quality," this step will set the course for much of the rest of the quality management process.

GAO's primary customers are the specific congressional committees or Members of Congress who request GAO's best-known products—our blue-covered reports and our congressional testimony. Yet in a broader sense, GAO's real customer is Congress as a whole, and by extension, the people of the United States. GAO's products also prove useful to other people and groups—for example, executive branch officials and the media.

Our first step will be to find out what our primary customers expect from GAO. In May and June of 1992, teams from GAO will interview all 535 Members of Congress. GAO staff will also contact the staff directors and minority staff directors of all congressional committees and subcommittees, as well as a sample of the committee staffers. Later, we plan to survey representatives from executive branch agencies and from the media. The result, we hope, will be solid information on what our customers need and expect.

Our customers' needs, however, are not the only factor by which we can define the quality of our products; that definition must also take into account GAO's stated vision, mission, and guiding principles. Sometimes this may force us to disappoint an individual customer. An objective audit or evaluation may not yield the findings expected, or hoped for, by the committee or Member who requested it. GAO must maintain its objectivity, its accuracy, and its other values to preserve its integrity as an organization useful to *all* its customers.

Goal 2: Analyze work processes

Our second goal will be to analyze our key processes—those that are essential to our work. Because better processes mean better products, this effort will help us serve our customers even as it makes the agency a more productive and rewarding workplace.

After our surveys give us a better sense of our customers' needs, we will use that understanding to determine which of our processes most affect our

ability to meet those needs. We will then focus our analysis in those areas. Even during the months before the survey results are available, however, we will have plenty to work on.

Our top priority is to look at a process that has often been a source of some distress to people inside and outside GAO: report development, or the entire range of activities from the start of a job to the publication of a report. Problems anywhere in this cycle can delay our products and frustrate both our staff and our customers.

We will also examine the planning process, which governs how we decide what work to do—that is, how much of our work should concentrate on broad, high-impact issues (such as the budget deficit), how much should cover narrower issues, and how we should set these priorities. In addition, the plan calls for us to look at GAO's process of determining rewards, recognition, and compensation, which may need to be adjusted to fit the quality management philosophy.

Goal 3: Expand implementation

The plan also sets out an approach for expanding quality management throughout GAO over the next two years. The shift will be gradual, involving only a few units at a time and following a systematic approach within each unit. There are several reasons for this measured pace: First, GAO must maintain its regular level of activity even as it makes these changes. Second, GAO is not equipped to provide complete training in quality management to its entire staff simultaneously; training will be more manageable if it is staggered.

QUALITY MANAGEMENT IS NOT A MAKEOVER THAT CAN BE APPLIED ONCE AND BE DONE WITH; IT IS A COMPREHENSIVE SYSTEM THAT TAKES TIME AND EFFORT TO PUT INTO PLACE.

Most important, however, is the fact that the move to quality management represents a complete retooling of the organization and its culture. The approach is not a makeover that can be applied once and be done with; it is a comprehensive system that requires considerable time and effort to put into place. Such broad-based change cannot be imposed overnight.

In the short term, GAO must convert its existing organizational structure into one that will help units take steps toward the new system. That structure will evolve as we gain experience; ultimately, quality management will be an integral part of regular operations across the agency.

Some parts of this structure are already in place. GAO's Quality Council provides overall leadership; other teams now forming at various levels will eventually be part of an agencywide network. In addition, the two pilot projects, which have been under way for more than a year, are serving as a proving ground for quality management practices. Other GAO units will be able to learn from the pilot programs' experiences.

Additional goals

In addition to the three major goals, the plan also establishes seven other objectives for the next two years. These include:

• *Educating ourselves in quality principles and methods.* GAO plans to develop a comprehensive program to teach the quality process, problem-solving methods, and other skills people need in order to participate. Practical training will be provided on a "just-in-time" basis—that is, as each unit is ready to use the knowledge. At the same time, quality management concepts will be added to existing courses for supervisors and managers.

• *Communicating throughout GAO.* GAO must work to create a communication system that encourages its people to offer ideas freely and candidly. Over the long term, we will analyze other organizations' methods and consider new technology that might help communications within GAO.

THE IDEA OF MEASURING QUALITY IS STILL NEW. GAO WILL EXPERIMENT WITH ALTERNATIVE APPROACHES IN THE HOPE OF DEVELOPING A RELIABLE, USEFUL STANDARD OF MEASUREMENT.

• *Recognizing and rewarding quality efforts.* GAO must determine how best to adapt existing reward, recognition, and compensation programs to the philosophy and principles of quality management. To guide our efforts, we will survey all GAO employees—as well as outside organizations—about what kinds of rewards and recognition they value most, and we will assess the impact of the existing compensation system on the success of quality management.

• *Building quality concepts into our planning processes.* Ideally, planning translates the organizational vision and mission into practical operations. We will examine GAO's planning process to find out whether we truly make this link.

• *Using employee suggestions.* GAO hopes to set up an employee suggestion system that enables all employees to share their ideas for improving operations. This will provide another opportunity for everyone to play a role in the agency's continuous improvement.

• *Measuring quality.* GAO's traditional measurements have served as yardsticks for assessing individual or unit performance, not as tools for understanding and improving our methods. Nearly all the organizations we studied told us that the idea of measuring quality is still new and that few standards exist. GAO will experiment with alternative approaches in the hope of developing a reliable, useful system of measurement.

• *Using "benchmarking" to learn from others.* Benchmarking is a formal technique for identifying practices from other organizations that may offer examples for one's own. To do this, we must first understand our own operations well enough to know what approaches from elsewhere might apply. GAO employees who plan to use benchmarking will receive training in this technique.

Real changes

At GAO, most of us have a strong but vague sense that "we already do quality work." We work hard and well, and we consistently push to work even harder and better. So how will quality management efforts help improve performance that is already high quality?

To begin with, it will sharpen our understanding of what "quality" means. Once we begin to define quality as how well our products serve our customers and ourselves, we will be able to focus on improving the procedures that make a real difference in our work.

The key point here is that we need to think broadly and creatively about new ways to change the way we work every day. Leaders in quality management agree that organizations achieve significant improvement not just by finding better workers, but by finding better ways of working.

For example, consider GAO's long-standing "report review" process—the gauntlet of fact-checking, supervisory clearances, editing, and re-editing that every GAO audit or evaluation must run on its way to being issued as a blue-covered

GAO report. Report review, which affects virtually all of GAO's written products, reflects the time-honored tradition of ensuring quality by inspecting products after they are created. Under the present system, a draft report may undergo dozens of separate readings by officials at various levels. After each critique, the evaluators working on the project revise the draft to incorporate the reviewer's comments. The underlying premise seems to be that the quality of the report increases with the amount of review.

Sometimes, however, the most obvious results of the process are delay and frustration. We routinely inform customers that it will take six months for GAO's findings—findings on which they may already have been briefed by GAO staff—to make their way into blue covers. No matter how reasonable the delay may appear to GAO, to the customer it's just that: a delay.

ATTEMPTING TO WORK HARDER WHILE USING THE SAME PROCESSES WILL MAKE ONLY A SLIGHT DIFFERENCE IN RESULTS. REAL IMPROVEMENT REQUIRES FUNDAMENTAL CHANGES IN THE SYSTEM.

GAO has not ignored this dilemma under its traditional system of management. For instance, GAO's General Government Division (GGD) has worked for years to cut down the time it takes for issuing a report once the audit work is done. Despite the division's best efforts, however, no breakthroughs have occurred. For five years, GGD's annual average processing time has hovered around a mean of 175 days—sometimes a little more, sometimes a little less, but always within a week or two of that average.

From a TQM perspective, this lack of progress is understandable. W. Edwards Deming, one of the formative thinkers in quality management, has noted that the results of stable systems tend to vary around a mean. By definition, then, results will be above the mean half the time and below it half the time—but within upper and lower limits, as the GGD experience demonstrates. Attempts to work harder while using the same processes may make a slight difference, but results will still fall within the same range of variation. The only way to lower the mean itself, Deming explains, is to make fundamental changes in the system.

Accordingly, both of the pilot projects are looking at ways to improve the process of report review. The pilot program in GAO's National Security and International Affairs Division (NSIAD) is working on getting blue-cover reports written and out the door, not six months after the audit work is completed, but within four *weeks*. And one of the teams in the GGD pilot program has set a goal of shortening the average time between the presentation of a briefing and the appearance of the formal report from 94 days to seven.

NSIAD's streamlined version of report review puts into practice another TQM tenet: the idea of "building in" quality from the start, rather than relying on a series of after-the-fact inspections. Under the procedure being tested, all the people involved in a project—workers as well as reviewers—meet early on to determine, first, the content and direction of the report, and later, its message, structure, and tone. After the report's authors produce a draft, the reviewers see it simultaneously—instead of in succession, which often leads to conflicting advice and repetitive efforts. All participants then iron out their differences in one last conference, not through marked-up drafts. The pilot project has tested this procedure on several jobs and found that it saves time, effort, and frustration.

An investment of time

The shift to quality management will hardly be easy for us at GAO. Such a sweeping overhaul requires major changes not only in the way we do things, but also in the way we look at things. We will need to learn how to break out of our old habits and traditions.

SUCCESS THROUGH QUALITY MANAGEMENT WILL NOT COME AT ONCE. BUT GAO HAS TAKEN THE FIRST STEP BY ACKNOWLEDGING THAT A GOOD ORGANIZATION CAN, AND MUST, BE MADE EVEN BETTER.

The basic methods of TQM are similar in many ways to the audit work with which we are already familiar: Decisions are based on facts, and progress requires thoughtful analysis by trained evaluators. But the approach also requires that we apply a discipline to solving internal problems that has not traditionally been a part of GAO's culture. That means we must restrain our tendency to seek immediate solutions.

In fact, the difference that will probably prove the most challenging for GAO's people to accept is that quality management requires patience. Success will not come quickly or suddenly. Organizations that have successfully adopted TQM tell us that while some improvement may be evident within a fairly short period, it can take five years or longer to realize the full benefits of the changes in principles and philosophy.

We must take a lesson from organizations that have tried to implement quality management too quickly, without the necessary knowledge and commitment. Experts tell us that 90 percent of the organizations that decide to adopt TQM quit too soon—abandoning the effort before it has had a chance to take root and make a difference.

GAO has planned to take two years to accomplish the first steps of implementing quality management; some organizations take longer. In developing the plan, GAO's leaders tried to balance the desire to involve all employees as soon as possible against the need to proceed realistically, considering the constraints of our resources and work load. We hope GAO's people, the customers we serve, and the other agencies that are watching our example will view the plan for what it is—a good-faith effort to chart the initial steps of what will be a long journey. What is important is that GAO's leaders have taken those first steps, by acknowledging that a good organization can, and must, be made even better. •

1. *Quality Improvement Plan: Early Implementation* (GAO/QMG-92-1, November 1991).

2. See *Management Practices: U.S. Companies Improve Performance Through Quality Efforts* (GAO/NSIAD-91-190, May 2, 1991).

EXPLORING
QUALITY MANAGEMENT

3

SOME THOUGHTS AT THE OUTSET

Joseph Juran on bringing TQM to government

Dr. Joseph M. Juran, Chairman Emeritus of the Juran Institute in Wilton, Connecticut, visited GAO headquarters last spring to share his thoughts on quality management with Comptroller General Charles A. Bowsher; Mary R. Hamilton, Director of the Office of Quality Management at GAO; and Allan I. Mendelowitz, Director of the Trade, Energy, and Finance Issue Area in GAO's National Security and International Affairs Division. The accompanying piece is an abbreviated text of their conversation.

HAMILTON: Many private-sector organizations are adopting total quality management and having success with it. Now TQM is starting to catch on in government. We ourselves are pursuing the idea at GAO. Do you think the TQM principles that work in industry can work in the public sector?

JURAN: I certainly do. But as you say, Congress and the executive branch are just starting to get interested in quality programs. For a long time, I think, that wasn't the case, largely because they just assumed that quality had always been a goal and that they were already achieving it with some of the old methods. This was true for years, not just in government but in industry as well, although by now the reality of things has hit home in the private sector and companies are responding. In government, it's really just beginning to become apparent to people that if anything's going to happen, you've got to set an institutional goal of improving performance—not just of holding things on an even keel and putting out fires, but of actually improving year after year.

BOWSHER: I think you're right that putting out fires isn't enough. One of the reasons we began to do general management reviews of the different agencies is that we could see that many widespread or recurring problems were traceable to a relatively small number of management weaknesses. If you could correct these underlying problems you could cut down on the crises.

JURAN: It's really a very useful analogy. Fire breaks out somewhere in town and all the apparatus converges—bells and sirens, plenty of flashing lights and whatnot—to get the fire extinguished as quickly as possible. You put it out and that's in some measure satisfying. But if it's your intention to prevent future fires, you've got to go further. Now you send a team in to sift the ashes and see how hot it was over here versus over there. You reconstruct the cause of the fire, then you do the same thing for a number of other fires, and before long you can see that most fires stem from a relatively small number of causes. So now you have the data you need to make changes. You have the basis for establishing new rules or passing new legislation as to combustibles and storage and all that sort of thing.

We call this Santayana review. You remember the philosopher George Santayana; one of the things he's known for is having said that those who do not study history are doomed to repeat it. That certainly applies here. Unless you want put out one fire after another indefinitely, you've got to go in and learn the causes of fires and then make improvements.

BOWSHER: One of the problems the executive branch agencies face is that their leadership doesn't stay long enough to make these things stick. None of these programs gets accomplished overnight. You've got to be willing to commit a number of years to the job if you're going to have an impact.

JURAN: That's especially true considering the differences between industry and government. The rules for how you get things done are totally different, and not everybody is sufficiently nimble to figure that out during the time they're in Washington.

MENDELOWITZ: When you talk about adapting TQM principles to government as opposed to the private sector—is it necessarily more difficult, or merely different?

JURAN: Just different, but *very* different. In government, an awful lot of people can say no to things. Decision-making in industry isn't nearly so diffused. Leadership out there may be autocratic, but that makes it possible to get decisions, right or wrong.

MENDELOWITZ: Is that the main difference?

JURAN: Well, it's one. Another is in how organizations see success. The major goal of any government agency is to carry out its mission—see to the national defense, get the checks out to retirees, that sort of thing. The financial yardstick—the whole matter of handling money efficiently—was not important to government during all the decades when the country was flush.

In the case of industry, though, the financial yardstick has always been terribly important. At the top of these companies, it determines who survives and who doesn't.

That difference is one of the hardest to grasp. It's very easy for somebody moving from industry to government to assume that his mission is going to be cost reduction. But that kind of thinking will get him precisely nowhere, simply because his real mission will be something altogether different: to carry out the mandated responsibility of the agency as set forth in its charter.

BOWSHER: Considering the federal deficit, though, and the pressure that all agency budgets are under, money's going to become a bigger factor.

JURAN: I think that's certainly a part of what's happening. If quality management were to help your agency continue to deliver services even when your budget's being cut, then it would show others in government that quality management makes sense. The Defense Department comes to mind. The Pentagon faces enormous cutbacks, yet it could fight off most of the effects of budget cutting for a decade just by cutting down on the number of times things need to be redone.

HAMILTON: Is TQM in government starting to show results?

JURAN: The government's quality programs themselves—what there are—are very new. We've seen people like the Federal Quality Institute stimulating pilot projects among the agencies. The Pentagon people are starting to do interesting things with quality management—partly exhortative and partly substantive. But as far as measuring the results that have been achieved, there's a big information vacuum out there. Hardly anything useful is going on as far as evaluating results.

You see some islands of excellence emerge—a manager here or there just gets fed up with what he sees and creates the means of improving things. But nobody's been out there drawing together all these experiences and stimulating something really big. Exhortation is one thing, but what really stimulates people is seeing results. They know something's doable because it has already been done. That's the way that quality catches on within a given organization; that's how it has caught on in industry, and it will probably follow the same course in government.

MENDELOWITZ: Success breeds success.

JURAN: Exactly. When agencies can cite units that gave faster service to constituents, or that were able to perform well in the face of budget cuts by improving their processes, they might start to make quality improvement goals a part of their annual business plans. That's the way to perpetuate change, to institutionalize it.

MENDELOWITZ: In your experience, then, do organizations make the transition to TQM more successfully if they go at it all at once, or area by area?

JURAN: It doesn't matter. Either way, they're going to end up using test sites, either deliberately or because it just works out that way. When you try to push the whole organization—that is, if it's a big organization—it never moves forward on a broad front. It moves in single file. The divisions are not equally busy: In one division, the general manager has an awful lot on his plate and can't take the time for something new; in another, there's simply no enthusiasm for the new venture; in another, there's a crisis that has to take top priority. Ability or willingness to get involved is going to differ from one division to the next. So what you end up with is somebody who is enthusiastic, who feels able to add quality management to his present approach, who perhaps is young enough to be willing to take the risk.

So you've got a test site. And if one test site gets good results, other managers will want the same results and establish their own test sites. As the results spread, the top people begin to ask the laggards: Is this something that can't happen in your area? So in due course, they all move, but not simultaneously—even if top management wants them to.

HAMILTON: What can we in the public sector offer people as incentives to participate?

JURAN: Whether it's the public or the private sector, there are two main ways in which to provide people with some kind of return for their participation.

If their participation is voluntary, we use recognition, public acknowledgment. Human beings have a bottomless capacity for accepting recognition. It doesn't have to be financial; it can be a photo in the company newsletter or a special dinner.

The other form of incentive is to tie improvement to the job itself, to make it a part of the contract between the company and the employee, part of the job description. In this case, participation is not voluntary: Part of your job will be to sit on a quality improvement team and help it carry out its project. And when that team is done, you'll be on another. And then another. It's your job.

So where participation is mandated that way, the practice is to weave that into the basic compensation system, which involves an annual review and some sort of decision on rewards. Once again, those rewards aren't merely financial. I mentioned quality management efforts at the Pentagon, for instance. When the day comes when you can point to several field officers and say these people have reached general officer grade by virtue of what they've done with respect to quality—then you'll know that some real incentives are in place.

MENDELOWITZ: What about an organization such as ours, where you're introducing something people had not been expecting?

JURAN: In that case, there's no need to scrap your existing evaluation system, but rather to add a new element: performance on improvement. Right now you've got things in there to the effect that a manager's got to meet deadlines, got to stay within budget, got to meet quality standards. But you've probably got nothing to the effect that he's got to *improve* quality as part of his job. That should be the new element.

Just how you evaluate that element, and how you provide compensation, will depend on many factors specific to your organization. We haven't really learned how to evaluate performance on improvement; it's a new variable in the equation, a new parameter. So all you can do is fall back upon your own supervisory experience for a few years, then analyze how it's being done to see how it can be done with more precision. From the start, though, you simply must change the evaluation system. If you don't, you're sending people a pretty strong signal that nothing has changed, that nothing new is really expected of them.

MENDELOWITZ: Yet there will be some people who just aren't able to adjust, isn't that so?

JURAN: It is, but if they struggle against it or even leave, it's not because they're against quality. Nobody is against quality. It's simply that lots of people would rather not change the existing way of doing things. No organization can impose a managerial or technological change without some impact on the social structure. There's going to be a social consequence within the organization. You can announce that quality is now the top priority, but then whatever used to be the top priority is now second, and the people who work in that area now feel downgraded. For one thing, they may have more trouble getting their share of the budget. But beyond that, there's always a social consequence.

You can divide the spectrum of people into three parts. You've got the people who are really eager for change. They are just itching to take a crack at the improvements they think ought to be made. Of course, since they are the advocates of these improvements, success will redound to their benefit as well as to that of the organization.

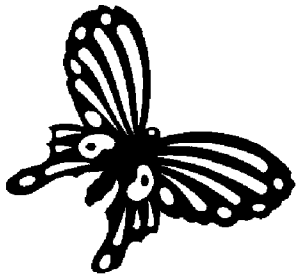
Then there's the great majority of people, who simply say, "Show me." They are not convinced by all the advocates; they've been taken in before by others. But they *are* convinced by results. If the test sites get results, then they'll be willing to try it themselves. But somebody else has to take the risk before they will.

Then at the tail end you've got the real recalcitrants. They are just against change. They may offer any of a variety of reasons, but they're just dug in. The time comes, though, when they are part of a vanishing minority, and they can't have that. So they get dragged in despite themselves.

BOWSHER: Sometimes you've got to work hard to convince people that they're part of a team.

JURAN: That's a good point you make. People tend to be loyal to their own job, their own function. They make a career of their function. They may feel they own the function. But all the functions have to work in tandem. A person in one function is on the same team as a person in another function.

Here's one way in which an organization can resolve to pursue quality management and fall flat on its face. Management says, first, what does the customer want? So they send out market researchers to find out. They throw that information over the wall to the designers, who come up with a technological response to the customers' needs. Then that gets tossed over another wall



to the people who must design a process to produce those goods. In many cases, though, the design is not producible, whether for lack of existing equipment or knowledgeable people or whatever. Whatever it is they come up with, they throw over the wall to the people in the factory to produce. And *they* throw it over the wall to the people who will have to sell it and service it. This goes on and on.

So every step of the way, people's intentions may be good, but they're just creating problems for all the other people downstream. The time it takes to launch the product is lengthened enormously by all the redoing that has to be done. And even though the cost is very low at the early stages, once you start producing a million of something you start to realize how expensive it is to do market research and design and so forth in isolation from the other functions.

Here's how it ought to be done. When the Ford people went after the Taurus, they created Team Taurus. All the different departments presided collectively over the development of the car, so that their contributions came concurrently rather than consecutively—no throwing things over walls. That was a marvelous job of planning, a quantum leap for domestic industry.

And now you see this going on down at the bottom of companies, where instead of people having a boss to assign them what to do—*you* do this, *you* do that—they are trained to work cooperatively, to supervise themselves. They don't have a boss. They decide among themselves who is going to do what and how to redesign the process.

You know, there is no reason why you must have a boss. When a bunch of kids go off to a vacant lot to play ball, they don't have a boss. They pick the game, choose up sides, decide who is going to play what position, who'll referee, and so on. Life can be lived that way. •

MEAN STREETS

Alex Kotlowitz

THERE ARE NO CHILDREN HERE: THE STORY OF TWO BOYS GROWING UP IN THE OTHER AMERICA

New York: Doubleday, 1991. 324 pp.

By Lowell Dodge

In 1988, *Wall Street Journal* reporter Alex Kotlowitz told LaJoe Rivers that he was thinking of writing a book about the children living in her inner-city Chicago neighborhood. She replied, "But you know there are no children here. They've seen too much to be children."

Kotlowitz apparently agreed; in *There Are No Children Here*, he shows us just what two of LaJoe's sons have seen. Kotlowitz's narrative follows the boys—Lafeyette, age 12 when the book begins, and Pharoah, three years younger—from mid-1987 to mid-1989. The result is an eloquent and compelling documentary of the reality of growing up in a Chicago public housing project.

The strength of Kotlowitz's chronicle lies in the author's careful balancing of simple, direct observation with an impressive amount of investigative research. The combination produces a set of portraits that are at once brilliant in their insight and horrifying in their grimness, even for those desensitized by the incessant images of gangs, guns, and drugs that routinely assault all of us via television and film.

Gunfire was virtually an everyday occurrence in the lives of Lafeyette and Pharoah. The sound of gunshots would send the boys and their mother and siblings crashing out of their first-floor apartment to wait in the relative safety of the hallway. Once, when shooting erupted while the boys were at a playground, Pharoah and a friend took cover amid the meat scraps and empty pizza boxes in a large trash container. They emerged half an hour later to see paramedics assisting a young girl who had taken a bullet in her leg.

Lafeyette had first witnessed death at age 10, when a young member of a local gang, wounded by a gunshot, ran into their building. Lafeyette, coming out of his apartment, saw the boy bleed to death where he had fallen on the stairs. Two years later, his blood still stained the stairwell.

In the two years Kotlowitz spent with Lafeyette and Pharoah, violent death claimed five close friends and family members. Any one of these deaths would have substantially altered the boys' view of life. Kotlowitz probes the circumstances of two killings. One friend, Calvin "Bird Leg" Robinson, a teenager who had a way with dogs, was shot point-blank by a rival gang member outside the boys' building. The boys, who were nearby at the time of the killing, attended the funeral. The fact that little separated Bird Leg's life from their own did not escape them.

The second case was even more difficult for the boys because of its senselessness. Craig Davis, a neighbor and friend who had often organized impromptu talent shows in the housing

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project, was gunned down by an agent from the Federal Bureau of Alcohol, Tobacco, and Firearms in an apparent case of mistaken identity. Though neighbors and teachers maintained that Craig had never been a gang member and never carried a gun, the BATF insisted that this Craig was the same gun trafficker named Craig whom they had been seeking.

During the period covered by the book, Lafeyette and Pharoah survived in a physical sense, but the psychological damage they endured is clear. Lafeyette withdrew emotionally and was plagued with nightmares and flashbacks. When Kotlowitz asked him at one point what he wanted to be, he replied, "If I grow up, I'd like to be a bus driver"—*if*, not *when*. Pharoah, a gifted child intellectually, developed a debilitating stutter. Their mother spent $80 of her meager income each month to buy her children burial insurance.

Kotlowitz's narrative identifies and tracks the societal and institutional forces that shaped the boys' environment. To help the reader understand the influence of gangs, Kotlowitz looks closely at two local gangs, the Disciples and the Vice Lords, and provides an illuminating portrait of the Vice Lords' leader Jimmy Lee. To examine the workings of the welfare system, he describes the proceedings of the local public welfare agency, when, in a mockery of due process, it cut the Rivers family's benefits for two months.

Kotlowitz uses memos from the Chicago Housing Authority (CHA) to highlight incompetence that would have been laughable had the consequences been less serious. In the spring of 1989, CHA discovered some 2,000 stoves, refrigerators, and other appliances—some new in their cartons—that had been delivered 15 years earlier to the basement of the Rivers' building and apparently forgotten. The appliances had long since been ruined by a sewage flood that went unattended for years.

The book also takes an enlightening excursion into Chicago's criminal justice system, as experienced by the boys' older brother Terence. Unable to escape the draw of local gangs, Terence had begun dealing drugs. Later, he developed a knack for breaking into coin-operated video games. By the time he was 18, he had been arrested 46 times for various offenses, and during the period covered in the book, he began serving a prison term. His avoidance of incarceration up to 1989 reflected in part the state of the Cook County jail: in 1988 alone, the jail set free 25,000 accused criminals because it did not have room for them.

Over the two-year period, Kotlowitz avoided going to bat for the family, even where a minor bit of advocacy on his part might have helped them out. He did buy the boys occasional gifts, such as new jeans or sneakers when needed, and he used a $2,000 prize he earned for a *Wall Street Journal* story on Lafeyette to bail out Terence when he was first arrested. After he finished his research, Kotlowitz says, he broke his "pact as a journalist to remain detached and objective" to help Lafeyette and Pharoah get into private schools. Proceeds from the book pay their tuition.

Overall, the book itself adheres to rigid journalistic standards. Kotlowitz maintains a value-free neutrality in his utterly straightforward descriptions. He makes no judgments, leaving that entirely to the reader, and he steers clear of discussing policy issues. But his neutral tone evokes outrage far more powerfully than if he had expressed it himself along the way.

It is worth noting that GAO figures into *There Are No Children Here* in two ways. Kotlowitz's bibliography includes the report *Public Housing: Chicago Housing Authority Taking Steps to Address Long-standing Problems* (GAO/RCED-89-100, June 8, 1989). And he credits CHA official Velma Butler, formerly of GAO's Chicago Regional Office, with assisting his research. •

CLEARING THE AIR

Richard Elliot Benedick

OZONE DIPLOMACY: NEW DIRECTIONS IN SAFEGUARDING THE PLANET

Cambridge, Massachusetts: Harvard University Press, 1991. 300 pp.

By Timothy Minelli

It sounds like the plot of a bad 1950s science-fiction movie. Chemicals in our fast-food containers and deodorant sprays slowly wander up to the stratosphere, where, after about 50 years, they begin destroying a layer of atmosphere that protects the good people of Earth from radiation.

But the story is true. And it illustrates several points about the nature of pollution (or, to use a more inclusive phrase, "environmental degradation") and our global environment. Recent scientific discoveries verify that pollution is *transboundary*; that is, it does not recognize national borders, and local actions can have cumulative, catastrophic effects on the planet and its inhabitants. Efforts to combat global environmental problems, such as ozone depletion, deforestation, species loss, and global warming, hinge on the ability of nations to take concerted, timely, and preventive actions before permanent damage occurs. Unfortunately, international cooperation often takes decades to cobble together. When consensus is reached on a course of action, it often falls far short of the demands that today's environmental exigencies place upon it.

Fortunately for the good people of Earth, somehow 47 countries agreed in September 1987 to the Montreal Protocol on Substances that Deplete the Ozone Layer. The protocol called for reductions in use of several man-made ozone-depleting chemicals, particularly chlorofluorocarbons (CFCs). Richard Elliot Benedick, a former Deputy Assistant Secretary of State, served as the principal U.S. negotiator during most of the talks on the Montreal Protocol. In *Ozone Diplomacy: New Directions in Safeguarding the Planet*, he offers an enlightening insider's account of the negotiations and presents the agreement as a model for international cooperation on environmental protection. (A portion of Benedick's book was adapted as "Diplomacy and the Ozone Crisis" in the *GAO Journal*, Issue #6, Summer 1989.)

Anyone who scoffs at international diplomacy should read Benedick's account of the saintly patience and diamond-cutter's precision that negotiators used to keep the protocol deliberations alive.

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The book's middle chapters detail the countless meetings, debates, setbacks, and surprises that led up to the protocol's enactment. Benedick describes how the U.S. State Department and Environmental Protection Agency managed to place the United States out in front on the protocol negotiations despite the highly antiregulatory bent of the Reagan administration. The eventual strength of the U.S. position was finally determined by President Reagan himself, whose sensitivity to the issue, Benedick points out, may have been influenced by the recent removal of two skin cancers on his nose.

Compared to the European Community, however, the United States was a pillar of consistency. Except for what was then West Germany, most European countries showed scant interest in regulating CFCs. In fact, some Europeans suspected the Americans of using an ozone scare to cloak commercial motives; after regulating CFCs domestically in 1977, the United States had lost world market shares in these substances to the Europeans. That was not the only dispute that threatened to doom the agreement; negotiators had to deal with issues of monitoring and enforcement, technology transfer, and intellectual property rights, as well as the Southern hemisphere's demands for equity and financial assistance. Benedick appropriately credits the persistence of U.S. leadership and the skill of such diplomats as United Nations Environment Programme Director Mostafa Tolba for the eventual success of the negotiations.

The Montreal Protocol negotiations stand as a model for future environmental agreements. The book's final chapter is directed to those now negotiating an international framework agreement on climate change that is scheduled to be signed at the June 1992 United Nations Conference on Environment and Development in Rio de Janeiro. Benedick points out that these negotiators face some of the same issues that arose with the Montreal Protocol, such as uncertain science and immediate economic costs.

Experience from the protocol negotiations, he says, suggests several elements of a new kind of diplomacy for addressing such global ecological threats. These elements include (1) a strong role for science—that is, scientific evidence on likely environmental dangers, not short-term economic interests, should guide negotiations; (2) public involvement in the negotiating process, from both nongovernmental organizations and regulated private-sector organizations; (3) leadership by individual nations, particularly the United States; and, perhaps most important, (4) care to make the final agreement a flexible and dynamic instrument, one that allows for modification and addresses concerns of equity between nations.

Indeed, the Montreal Protocol has an almost Constitutional quality in its balances and equity considerations. While the agreement insists nations meet rigid schedules for phasing out ozone-depleting substances, it allows a grace period for developing countries. It employs carrot-and-stick incentives for compliance, offering developing countries financial and technical assistance to implement the agreement and directing trade sanctions at countries that do not sign on. Also, as with the U.S. Constitution, the protocol is a living, flexible document (or, as the environmental community aptly describes it, "organic"). It is amendable, as was demonstrated in a June 1990 protocol meeting in London. There, in response to new scientific data on rapid ozone loss, member countries agreed to phase out completely a host of ozone-depleting chemicals including CFCs, halons, carbon tetrachloride, and methyl chloroform.

Let's hope it works. As with any agreement, the ultimate success of this undertaking depends on implementation. Despite the growth in international environmental accords, little research has been done on compliance. For that matter, not much information exists for evaluating either the success of these agreements in protecting the environment or the merits of proposed agreements. The Montreal Protocol was the first environmental agreement that not only told nations what to do but also provided incentives to encourage them to do it. However, how these incentives actually work in practice remains a question.

Ecological dangers—species loss, toxic wastes, ocean and freshwater pollution, deforestation, climate change—and their threats to the security of all peoples are likely to rise to the top of every nation's agenda in the near future. Only timely, preventive, and cooperative actions among nations can prevent these threats from causing permanent environmental degradation. All of us can take hope in the Montreal Protocol's model of cooperation. Benedick provides a most important service both in telling the story of this unique achievement and in gleaning its lessons. •

MIXED SIGNALS

Sheila Jasanoff

THE FIFTH BRANCH: SCIENCE ADVISERS AS POLICYMAKERS

Cambridge, Massachusetts: Harvard University Press, 1990. 302 pp.

By Robert Goldenkoff

In the spring of 1989, the nation was in an uproar over a plant growth regulator called Alar. Though a boon to growers—particularly the apple industry, which used Alar to extend harvests and lengthen shelf life—the chemical was also suspected of causing cancer.

The Environmental Protection Agency (EPA) and the Natural Resources Defense Council argued publicly over Alar's threat. Schools and supermarkets purged their shelves of Alar-tainted apples. Actress Meryl Streep pleaded before a Senate subcommittee "to end experimentation on children." Meanwhile, more than five dozen scientists placed an ad in the *New York Times* attesting to Alar's safety. EPA and its advisory panel, charged with leading public policy, instead wound up chasing it. What went wrong?

In *The Fifth Branch*, Sheila Jasanoff uses the Alar controversy and a host of other issues as a means to examine the role that science advisory committees play in the regulatory process. This role is significant. She writes that the influence of these committees is pervasive, affecting whether we should "eat supermarket apples, use hair spray, . . . incinerate our wastes, generate nuclear energy, [or] release genetically engineered organisms into the environment."

The author, an associate professor at Cornell University, begins her study by describing the rise of scientific advisory committees and the constraints they face in trying to validate regulatory decisions. She observes that committees such as EPA's Science Advisory Board "offer a flexible, low-cost means for government officials to consult with knowledgeable and up-to-date practitioners in relevant scientific and technical fields." Moreover, "they inject a much-needed strain of competence and critical intelligence into a regulatory system that otherwise seems all too vulnerable to the demands of politics."

Advisory committees came into being, Jasanoff explains, because a series of controversies between 1975 and 1980 brought to light serious flaws in the regulatory process. In most of these cases, an agency would regulate a particular chemical after doing an internal study. Outside experts would then dispute the agency's actions, forcing the agency to review its data and alter its original stance. In the end, the agency would withdraw its regulatory action, and, in so doing, damage its own reputation. "Collectively, these incidents fostered the impression that agencies could not be trusted to use science in a responsible manner unless they were supervised by a more neutral scientific authority, such as an advisory committee," Jasanoff writes.

A major reason for such "flawed decisions," according to Jasanoff, were the shortcomings of the two models upon which the advice was based. Under the "technocratic" model, scientists are "the validators of policies with high technical content." This contrasts with the "democratic" model, which calls for broad public participation in technical decisions. For Jasanoff, neither approach is up to the task of making regulatory agencies ac-

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countable for their decisions. In her view, either model can be co-opted by individuals pursuing specific political objectives.

For example, with the technocratic approach, good science is distinguished from bad science by means of peer review: Who better to control regulatory science than a panel of technical experts? Despite the intuitive appeal of this approach, however, the author cites several studies that show how peer review failed to uncover incidents of plagiarism, fraud, and misconduct. More important, other studies suggest that peer review works best when there already is general consensus over theories and methodologies—an infrequent occurrence in regulatory science.

The democratic model maintains scientific accountability using judicial review and open decision-making, as embodied in the Freedom of Information and Federal Advisory Committee acts. Yet this system too has its flaws. According to Jasanoff, judicial review fell out of favor as a result of inconsistent decisions and decisions that overturned regulatory agencies' "expert judgment."

Given the deficiencies of the technocratic and democratic models of scientific review, how can scientific advisory committees provide better oversight of regulatory agencies? Using EPA and the Food and Drug Administration (FDA) as case studies, Jasanoff shows how scientists and policymakers can accommodate one another.

EPA's Science Advisory Board (SAB) was created in 1974 to oversee the programs of the Office of Research and Development, the agency's research shop. In its early years, the "SAB was a dangerous ally, capable of functioning either as a scientific and political troubleshooter or as a lightning rod for controversy," Jasanoff writes. This was particularly true during President Reagan's first term, when, under Administrator Anne Gorsuch, SAB became highly politicized.

Once Gorsuch left, however, the panel's neutrality was restored, and a new spirit of cooperation developed between SAB and EPA. Jasanoff cites several reasons for this. First, a high priority was placed on restoring SAB's scientific credibility by using a more open appointment process and by recruiting a representative slice of the research community. SAB also limited itself to a strictly advisory role, staying far from policy decisions. A similar accord was reached between EPA and another of its advisory panels, the Clean Air Scientific Advisory Committee.

In the case of FDA, Jasanoff describes a different model of accommodation. Even though FDA had relied on an array of advisory committees since the late 1960s, their advice was often unproductive, she says. Using a series of examples such as the imposition of a partial ban on sulfites, she demonstrates how the validity of FDA's decisions was continually challenged.

More recently, however, FDA has developed a better relationship with its advisory committees. Unlike EPA's Science Advisory Board, which distanced itself from policy, FDA's advisers may employ non-scientific data and get involved in policy. Moreover, FDA's advisory committees structure their proceedings to more easily achieve consensus with the agency.

Following this detailed analysis of the role science advisory committees play in the regulatory process, Jasanoff arrives at a fairly simplistic conclusion. In regulatory science, "there can be no perfect, objectively verifiable truth." The best we can do, she argues, is hope for a "serviceable truth," a sort of regulatory middle ground where defensible science supports decision-making but also ensures that the interests of those at risk have been considered. Given her promise in the beginning of the book "to bring the modern scientific advisory process out of the shadows and into the limelight of public-policy analysis," her fence-straddling conclusion is a bit of a disappointment.

Readers should also note that Jasanoff takes a highly scholarly approach—and, accordingly, the book requires attentive reading. Those who are not already interested in the topic will not find the book engrossing in itself.

These, however, are minor criticisms. In 1971, scholar Martin L. Perl asked in an article in *Science*, "How have we gotten into so much technological trouble while getting so much well-intentioned and correct technological advice?" Two decades later, Sheila Jasanoff provides some cogent answers. •

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